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Universities Council on Water Resources
Journal of Contemporary Water Research & Education
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Water Education for Sustainability in Higher Education

Bruce Missingham[1] and Brian S. McIntosh[2]

Dedication to a Dear Friend and Colleague

This special issue on water education is dedicated to our colleague, Peter Oliver, who died on November 20th, 2012. Peter was a leading and passionate water and environmental educator in Australia. His photograph appears on the cover.

We would like to honor Peter by talking about how his life and work embodied and epitomized many of the key themes of this issue. Peter was a highly experienced educator and academic, with an approach to water education developed out of three decades of teaching in secondary schools, universities, community contexts, and professional workshops. Many of Peter's insights grew out of first hand teaching in classrooms, field trips, community meetings, and forums, of listening to and interacting with people from schoolchildren, through commercial fishermen and farmers, to water professionals from around the world. Certainly, Peter reflected critically on his educational practice and related it to academic knowledge and theory, as his papers in this collection discuss, but his approach was born from and centered on practical, thoughtful doing. Peter was continually involved in a process of learning how to be – and aspiring to be – a better educator.

Peter believed in getting students into the field: out into the environment where they could engage with it and the local people who knew it best, see and experience environmental issues first hand, be challenged to analyze those issues and think about responses and solutions. This is the immersive education that Bill Dennison and Peter write about in this issue. Experiential education was his stock in trade: field trips to investigate water resources issues in places like the Brisbane River, Stradbroke Island near Brisbane, the Mary River, the Murray Darling Basin, and the Kalgan River in Western Australia.

For Peter, experiential education in the environment was closely linked with problem-based learning – learning through engagement and analysis of actual problems in real-world contexts rather than classrooms. Getting out into water catchments and river basins enabled students to see and experience development impacts and environmental changes first hand. Learning in the field was one of the best ways to enable students to see and experience the complex relationships between people, water, and development. Field experiences pose real-world problems that require analysis from a range of different disciplines and the integration of those different knowledges. Field experiences require cooperation among students in groups, learning from different stakeholders, and consideration of technical and management solutions in relation to actual contexts.

Peter believed that problem-based learning was one of the best ways to enable students to integrate a range of disciplinary knowledge, social perspectives, and ways of thinking about water management problems into their work. Peter felt strongly that universities and university courses did not "do" integration very well. He was deeply skeptical about formal courses teaching integration or transdisciplinary methods. He would say, "The moment you put integration in a

specific subject, you've killed it, it's not integration anymore!" Integration and making connections across different disciplines was not a subject to be taught, but a process that students and water professionals needed to engage in – attacking a problem, drawing on existing literature, drawing on a range of disciplinary methods, gathering scientific and social science data, and considering the perspectives of different social stakeholders. It is a messy, challenging, and creative process – and ongoing. Mark Pascoe, CEO of the International WaterCentre, called Peter a "walking integrator."

Introduction to the Special Issue

Peter Oliver was the inspiration for a workshop on "Innovative Approaches to Water Education" we hosted at the International WaterCentre in Brisbane in November 2011, bringing together water educators from the International WaterCentre network around Australia, Fiji, China, and the United States. We met, listened to, and learned from each other, openly and positively, and had a little fun – a process which those who knew Peter would recognize as reflecting his generosity and sincere engagement. Several participants in that original workshop have contributed papers here; others have joined us along the way and added a great deal in the process. Those include water educators involved with the Integrative Graduate Education, Research, and Training program (IGERT) funded by the National Science Foundation in the United States, and an international network of universities associated with UNESCO's International Hydrological Program.

Water education for sustainability has emerged as an important field of practice in higher education in recent years, as demonstrated by this journal and recent international networks and workshops coordinated by UNESCO. Nevertheless, some recent commentators have argued that university courses on sustainable development and management of water are very few and far between, and so far are having little impact on the water sector or on improving the sustainability of water resources (Cap-Net 2008; Leendertse and Taylor 2011).

The water educators who contributed to this issue want to change that. We all aspire to education for social change in one form or another; that is, education that will "make a difference" in the professional lives of graduates and in the water sector. In the following papers we address questions such as, how do we educate emerging and practicing professionals to acquire knowledge, skills, and values to enable them to contribute to protecting water resources, and manage them sustainably? How do we educate such professionals to think critically and creatively about current water issues, be able to contribute new knowledge and participate in debates about sustainable development in theory and practice? How do we develop the capabilities and skills in such professionals to enable them to effectively integrate multiple disciplines and interests, and to influence policy development?

The papers presented here almost all come from reflecting on educational practice, rather than research as such. They have been developed out of reflection on the educational practice of university academics and out of professional desires to improve learning outcomes for our students, many of whom are practicing water professionals. That has meant that many of us have not contextualized our stories and analysis in educational theory or concepts, but rather ideas and educational strategies developed in practice with colleagues and students in the spirit of "learning by doing."

The first paper by McIntosh and Taylor gives an important context for the whole issue, and starts by outlining some of the challenges facing water sector professionals in the future, and in doing so, sets forth a persuasive justification for new and better ways of educating professionals in the water sector. They argue that water professionals will need to have strong leadership skills, and lead change within teams, organizations and institutions towards goals set by sustainability and Integrated Water Resource Management. Water professionals also need to be skilful integrators – able to draw upon and apply a range of technical and disciplinary knowledge to water management issues, and join technical, scientific perspectives up with social science and social perspectives in the analysis, development, and implementation of water management strategies. To achieve such

expertise and skills, McIntosh and Taylor draw upon leadership, organizational management, and learning theory to propose the idea of the "T-Shaped Water Professional" as a way of developing and teaching postgraduate courses in Integrated Water Resource Management and water sustainability. The T-Shaped Professional has a deep but narrow educational training and experience in a particular professional discipline (the trunk of the T), but capped off with a broad transdisciplinary education in aspects of science, social science, economics, and management needed to be a critical thinker, leader, and integrator in the water sector (the hat of the T). They conclude with some ideas about how we can educate such T-Shaped graduates.

The next two papers come from a very interesting project of collaboration, dialogue, and reflection between two highly experienced educators, Peter Oliver and Bill Dennison. Peter and Bill had regularly worked together across the previous two decades, but four years ago they began a collaborative writing project together that involved them sharing, reflecting on, analyzing, and writing about environmental and water education. The outcomes of that process include a book, *Dancing with Dugongs*, and the two jointly authored papers here. Sadly, Peter died before he saw this work published.

In "Popular Education for Water Sustainability: Three Lessons from Reflective Practice," Peter and Bill tell the story of commercial fishers affected by exclusion and a cyanobacterial bloom. As they show, their work with the fishers can be characterized as popular education, that is nonformal education aimed at collective action and social change. Peter and Bill draw out three lessons from the case. First, popular water educators need to know the people they work with, their knowledge, experience, and aspirations. Second, they should learn from their participants and enable the participants to learn from each other. Lastly, effective popular education has a strong emotional dimension that is just as important as thinking and doing – the heart should be integrated with the head and the hands, in Peter and Bill's words.

In the second of their joint papers, Bill and Peter reflect upon Bill's teaching of marine studies and coastal zone management at the university level to develop principles for a form of experiential education they call "immersive education." For Bill and Peter, "immersive education places students directly in the water environment that is home to their interests and uses the experiences they gain as a way to learn about, reflect on, and advocate for the better understanding and management of this water environment." They give examples from their own teaching when immersive education provoked in students strong emotional connections to the environment, that was process-driven and transdiciplinary, collaborative and democratic, and fostered critical thinking and new insights and perspectives.

In the following paper, Missingham continues exploring the usefulness of popular education principles and approaches, but in this case, within the university classroom. He briefly discusses the origins of popular education and participatory learning approaches and their growing influence in the field of environmental education, but quickly turns to an exposition of what has worked well in his own pedagogy of water and sustainability. Missingham highlights strategies of asset-based teaching and learning in which students' knowledge, experience, and heart-felt aspirations are turned into learning resources equally – or even more – important as the lecturer's expert knowledge. He also discusses problem-posing education, participatory learning underpinned by effective group facilitation techniques, and student construction of knowledge and theory (rather than uncritical consumption).

Next, we turn back to field-based education, which is a central theme of the following three papers. In "Cross-boundary Peer Learning in the Mekong: A Case of Field-based Education in Natural Resources Management," Xing Lyu, Phil Hirsch, and their colleagues present and analyze their experience in running the Mekong Learning Initiative research exchange program, which set out to create educational linkages and collaborative learning between postgraduate students at Yunnan University in China, Ubon Ratchathani University in Thailand and the Royal University of Phnom Penh in Cambodia. An important aspect of the program

is that it grew out of collaborations between academic researchers at the three universities and the University of Sydney, and aspirations on their part to try something new in terms of cross-boundary student exchange for research and learning in a region that has experienced increasing interconnections in other dimensions (such as trade, economic infrastructure, population movements, and political). Xing Lyu, Hirsch, and their colleagues characterize the program as cross-cultural, peer-based learning, and experiential learning. They describe in detail how they managed and facilitated the process, and the main learning outcomes. They draw out many useful lessons for transboundary and cross-cultural water pedagogy.

The next two papers come to us from academics involved in the IGERT program, funded by the U.S. National Science Foundation (NSF). The IGERT program has aimed to encourage and fund inter-departmental and inter-institutional initiatives that develop interdisciplinary and integrative experiences and skills in postgraduate research students.

As Pinter and his colleagues argue in their paper, "An 'IGERT' Model for Interdisciplinary Doctoral Education in Water-Related Science and Policy," the need to foster interdisciplinary and integrative approaches and skills is particularly relevant in water and watershed science. Their paper describes how the IGERT Watershed science program at Southern Illinois University has set out to facilitate the interdisciplinary processes and integrative skills being sought by the NSF. Their approach has been based on three key premises. First, they believe that "student training in multidisciplinary watershed science cannot be meaningfully multidisciplinary without meaningful collaboration between students and advisors from different disciplines." Therefore they adopted the organizing principle of the "cadre," consisting of 5 to 6 new Ph.D. candidates, each from a different disciplinary background, each year. Their second premise was to set the cadres the task of developing a research-driven assessment and management plan for a specific river basin. Thus the students had to work collaboratively on field-based and real-world problems. Finally, academic researchers from a range of disciplines collaborated in developing a suite of new interdisciplinary courses for postgraduate research students. Their account and examples show that the program was particularly effective in achieving transdisciplinary and collaborative group work by the IGERT fellows. Interestingly, they conclude with a discussion of the resourcing issues and institutional resistance they continue to face in running the program.

The penultimate paper is also about an NSF-funded IGERT initiative, this time in a collaboration between Kent State and Miami University to teach doctoral students about advanced sensors for freshwater science in a transdisciplinary and integrative way. Laura Leff and her colleagues present a range of effective education strategies developed in the program. Once again, taking students into the field was important, as was assigning them to work in small teams on applied research questions requiring research design, application of sensor technology, and the analysis and interpretation of sensor data. Their program also reveals the importance and effectiveness of being responsive to the career development needs of students. Leff and her co-writers designed and presented courses such as proposal writing, academic writing, and career opportunities and planning. Through internships, visits to industry, and other means, they also exposed students to the business side of remote sensing. Leff and her colleagues conclude with a succinct statement that will resonate with many of us: "The key to achieving inter-disciplinary training, in our view, is to give students a common problem to tackle and the tools to do so."

Finally, Camkin and Neto's paper makes a thoughtful conclusion to our special issue. They remind us of some of the big issues facing water resources development and management. They also remind us that multidisciplinary, interdisciplinary, and transdisciplinary all mean different things. What we are all probably aiming towards is transdisciplinary approaches to underlie truly integrative research and teaching. Camkin and Neto describe some of their approaches to achieving such transdisciplinary teaching in the Erasmus Mundus Master Course in Ecohydrology. They

draw methodological inspiration from Frierian ideas of dialogue and praxis (also associated with popular education and critical pedagogy mentioned in some earlier papers). Drawing on the previous professional experience of participants and challenging them to consider how water decisions and actions could be improved by Integrated Water Resource Management concepts proved fruitful. Learning in their courses became collaborative, as students' professional experience and knowledge was valued and shared with lecturers knowledge. At the same time, they analyzed, discussed, and learned through practical water problems in real world contexts.

Conclusion

In his article here with Bill Denison, Peter Oliver argues that you should know your students, build effective relationships with them, and be prepared to learn from them. We hope you enjoy engaging with and learning from the experiences of the authors as presented here in this Special Issue. If any of the ideas, experiences, or reflections presented resonate with you, then please contact the authors involved. Learning is not a one-way process and we all genuinely look forward to engaging with others to transform university learning into a force for positive and effective change across the water sector.

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References

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Developing T-Shaped Water Professionals: Building Capacity in Collaboration, Learning, and Leadership to Drive Innovation

Brian S. McIntosh and André Taylor

Abstract: As we progress into the 21st century, change is an increasingly central theme for water professionals and for professionals in sectors where water plays a central role. Building the capacity of professionals in water and closely related sectors to lead such change will be an essential component of the response to global water challenges this century. This paper provides a contribution by critically developing a concept, the T-shaped water professional, as a framework for the design of curricula for educational programs to build the capacity of water professionals to stimulate and drive processes of innovation and change. The T-shaped water professional concept integrates insights from leadership, organizational management, learning theory, collaboration, critical thinking, and praxis. In doing so, the concept provides a response to two basic questions – (i) what skills and knowledge do water professionals need to stimulate and lead change, and; (ii) how can we develop them?

Keywords: *Innovation, T-shaped professionals, leadership, double-loop learning, collaboration*

Change has been an increasingly central theme in water management since the 1980's and early 1990's. During this period the need to integrate different aspects of water resources management to effectively provide benefits and avoid problematic trade-offs across sectors, across different groups of peoples or environmentally became a significant focus of concern. The concern resulted in the Dublin Principles of 1992 and much subsequent research and action under the banner of integrated water resources management (IWRM) (Lenton and Muller 2009). IWRM can be interpreted as a movement focused on change – change in the way that water policy and management decisions are coordinated, undertaken and implemented, either institutionally, sectorally, or geographically. In this sense integration in water (resources) management isn't a state of being, rather it is a process of changing states of being (Jønsch-Clausen and Fugl 2001).

Focus on change in the water sector has continued to grow since the 1990's. Since then significant trade-offs between water uses (supply, ecological support, food, energy) for limited resources have become apparent and are now well recognized. These trade-offs include limits to electricity generation from a lack of available water for evaporative cooling power stations (PMSEIC 2010) and substantial increases in the water required to produce a unit of energy for transport as a consequence of crop-based biofuels being substituted for increasingly scarce and costly oil (World Economic Forum 2011). Our water systems require energy, our energy generation systems require water, our food systems require both water and energy for production and transport, and we (the world) seem to be reaching limiting trade-offs between these systems in terms of the underlying water resource – the so-called water-food-energy nexus. Water supply and food shortage crises are now ranked as the highest likelihood and highest impact social risks facing the world (World Economic Forum 2012). In an increasingly water-limited world as a consequence of population growth and changing rainfall patterns, the need to radically change the way in which essential services – water, wastewater, food, energy – are managed and delivered in a more integrated way has been argued for strongly (World Economic Forum 2011).

Beyond the details of the water-food-energy nexus, a growing body of literature in water management highlights the need to focus on better understanding and consequently managing processes of institutional and organizational change rather than focusing on technological improvement as one key to realizing sustainability goals (Brown and Farrelly 2009; Spiller et al. 2012; 2013; Thomas and Ford 2005). The broader sustainability literature has also focused on the need to better understand and manage the processes of change, or innovation, which are required to bring human activity into alignment with the "safe operating" bounds of planetary biogeochemical cycles and processes (Doppelt 2003; Leach et al. 2012).

For the ambitions of these writers, and more generally, of integration in water management to be realized, education forms a natural focus. Education constitutes an essential process for building the capacity of water sector professionals, and of professionals in sectors where water is either a major input (e.g., food or energy) or potentially subject to major negative impact (e.g., the ecological impact of urban stormwater runoff – see Walsh et al. 2005), to:

1. Recognize the need for innovation.
2. Develop innovative ways of changing that avoid creating problems elsewhere (geographically, sectorally, or to other groups of people).
3. Stimulate and drive processes of change.

But what should education programs for building such capacities focus on? Although innovation is a relatively new scientific field, with the first papers traceable to the work of Schumpeter in 1936 and 1942, the field has grown quickly, particularly since 1990 and now has an active, multi-faceted community and a large body of knowledge (Fagerberg and Verspagen 2009). The academic innovation literature, which has strong management and economics roots, is not the only source of knowledge regarding how the capacities of water professionals might be developed to take part in and drive change over the coming decades.

The primary aim of this paper is to synthesize insights from a range of literatures and bodies of knowledge into a coherent concept to describe and relate the skills and knowledge required for water professionals to drive innovation and change – a concept which might be used to structure the design of curricula for education programs for such professionals. By innovation we refer here particularly to more radical forms of innovation (see the next section), and by change we refer to more incremental innovation and non-innovative change processes. The concept developed in the paper is labeled the T-shaped water professional.

The concept of the T-shaped professional originally emerged from management literature in the late 1990's as a way of characterizing the set of skills possessed by professionals, typically from large organizations, who provide effective ways of solving problems and managing change by working deliberately across the boundaries of functional or organizational units (departments etc.) (see for example the use of T-shaped professional roles within British Petroleum as described by Hansen and Oetinger 2001). Such individuals are not generalists with limited knowledge in many areas. Rather they possess deep disciplinary or functional knowledge: they are specialists able to translate themselves into other constituencies (disciplines or organizational functions), and to translate the interests, objectives, and concerns of other constituencies into their own.

The insights and ambitions of the T-shaped professional as a model are now being translated into use in the water sector through the curricula of professionally oriented post-graduate education programs, such as those run by the International WaterCentre (see this paper and www.watercentre.org), and UNESCO-IHE (www.unesco-ihe.org). In this paper we critically develop the T-shaped water professional concept which has been used to underpin the Masters of Integrated Water Management and Water Leadership Programmes run by the International WaterCentre (IWC).

The IWC T-shaped water professional concept integrates content and process insights from literatures on leadership, organizational management, learning theory, collaboration, critical thinking, and praxis. The emphasis is rather more strongly on skills and knowledge for innovation and change than the concept of the T-shaped professional used by UNESCO-IHE (Uhlenbrook and de Jong 2012). Indeed the

T-shaped concept developed here was done so in response to two basic questions one might ask following an acknowledgement of the importance of change across the water sector – (i) what skills and knowledge do water professionals need to stimulate and lead change, and; (ii) how can we develop them?

The paper is structured to develop a set of propositions as to the skills and knowledge water professionals need to tackle the challenges of this century. We first describe what innovation is and why it is central to addressing water and broader societal challenges in the 21st century, then relate innovation to different levels of learning and develop an argument that skills for innovation are strongly related to the concepts of double loop and triple-loop (or level three) learning. We then examine collaboration as a key process and set of skills for effective double and triple-loop learning, and consequently also for successful innovation management. Next we critically review insights from the leadership literature on the skills and behaviors of successful leaders, and tease out the relationships between leadership, values, and ethics. Finally we end by integrating the insights from these literatures into the T-shaped water professional model concept.

Innovation and Learning

Tidd and Bessant (2004) articulate innovations as lying along a continuum from incremental to radical (see Figure 1). Incremental innovations are relatively easy to develop and manage changes that improve the performance of existing ways of doing things, usually building on existing knowledge. Managing incremental innovations is relatively well understood (but not necessarily well done). Radical innovations are more complex and difficult to develop and manage, involve generating new knowledge as well as applying it, but afford the possibility of qualitative, breakthrough change.

We must be honest as a society. We don't know exactly how we will adapt in future to cope with the water availability impacts of climate change, with rapidly growing urban populations, the intensifying consumption patterns of increasingly affluent populations, rising energy costs and the need to lower carbon emissions. We do not know what changes will be required to successfully adapt the structure and function of our water supply, food, energy and wastewater systems to the pressures of the present century. Certainly there are many insightful and useful attempts at visioning possible futures (e.g., UK Green Building Council and the Zero Carbon Hub 2010; World Economic Forum 2011), but these are the stimuli for change; they do not represent out-of-the-box, do-it-yourself futures to be implemented "as is." Indeed, no vision can be implemented "as is" – we know innovation processes often involve significant restructuring of both the innovation (to suit the implementation context) and the implementation context itself (for example, the re-structuring of an organization and its work) (Leavitt 1965; Spiller et al. 2013).

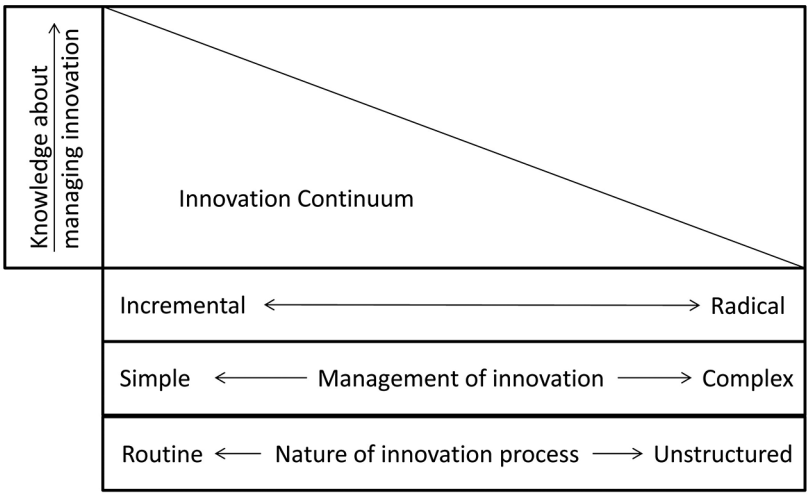


Figure 1. The innovation continuum (adapted from Tidd and Bessant 2004).

The kinds of innovations required may have to be radical and multi-faceted, involving changes across multiple levels of governance and action from community through to policy, through the application of multiple bodies of disciplinary and functional knowledge. They may require the economic, social and/or infrastructural restructuring of cities and regions (Boyer et al. 2009; De La Salle and Holland 2010; World Economic Forum 2011) through sets of radical innovations that affect entire systems of production and/or consumption – so-called systems, or socio-technical, innovations (Smith et al. 2005). There is no guarantee of success (see for example the alternate futures for cities envisioned by Boyer et al. 2009), although, to be clear, this depends on how success is defined, which is itself a contested and thorny issue.

For example, major elements of food production may need to re-localize and potentially even urbanize, to:

1. Make economic and logistical sense of using waste-derived inputs such as treated wastewater, stormwater, recovered biosolid nutrients.
2. Reduce the need for increasingly expensive energy inputs in the form of fertilizers, pesticides, and long distance transportation (De La Salle and Holland 2010).

Changes to urban planning and design at the city, precinct, and housing scale are likely to be needed if (i) we want to avoid damage to waterway health from stormwater runoff generated by impervious urban surfaces, and; (ii) create opportunities for harvesting significant volumes of stormwater for urban use (Brown and Farrelly 2009). Changes to urban planning and design which better integrate water into urban landscapes can provide enhanced liveability whilst minimizing raw materials input and reducing waste output (Newman 1999), and reducing urban vulnerability to disturbances including climate change induced heat waves, drought and flooding (Boyer et al. 2009). Such changes will move us towards the decoupling of economic activity from environmental impact and raw resource dependency (Schepelmann et al. 2010), a key sustainability aspiration for urban areas and societies more generally.

Here we put forward the argument that professionals are needed who have the skills and knowledge to be able to stimulate, drive, and manage innovation in the water sector and across related sectors (e.g., food, urban design and management, energy). Professionals are needed who are able to think critically and consequently challenge the status quo as we slowly seek to adapt the networked systems of production and consequent patterns of consumption that currently dominate (Van Vliet et al. 2005).

The notions of challenging ways of thinking and doing through learning can be found in the rich seam of thought which has risen from the work of Argyris and Schön (1974) into the differences between single loop and double loop learning. A range of definitions and interpretations of both types of learning are found in Tosey et al. (2012), summarized as:

- Single loop learning is concerned with improving the efficiency of current ways of doing through the recognition and correction of errors; of learning how to improve performance at an increasing rate without challenging underlying assumptions. Single loop learning is based in asking the question "are we doing things right?" (Romme and Van Witteloostuijn 1999), and is related to managerialism and the maintenance of the status quo in terms of power relations (Bokeno 2003).
- Double loop learning is concerned with learning how to question the values, norms, and relations of ways of doing, and of generating knowledge and changing how things are done through reflection and collective action. Double loop learning is based on asking the question "are we doing the right things?" (Romme and Van Witteloostuijn 1999), and is related to challenging the status quo, particularly challenging power relations.

Although not explicitly defined by Argyris, a third level of learning can be found discussed within the literature, often termed triple-loop learning (Tosey et al. 2012). Tosey et al. (2012) link single, double and triple-loop learning respectively to Bateson's (1973) level I, II, and III

learning, where triple-loop learning (or Level III learning) is defined as involving change in ways of knowing, or in underlying principles and purpose. Bateson, as discussed by Tosey et al. (2012), viewed Level III learning as rare, for it involves a fundamental change in the way an individual or group of individuals view the world, generate and use knowledge. He related Level III learning to religious or spiritual experiences, or the kinds of change that sometimes occur after particularly significant life events. One might relate triple-loop or Level III learning to asking the question "how do we decide what is right?"

These three levels of learning can be viewed as arranged along a spectrum from status quo preserving, incremental (single-loop) to radical (triple-loop or Level III). Here we put forward the argument that effective response to the challenges of the 21st century will require water professionals able to engage in, lead, and manage process of double-loop learning, and potentially also of triple-loop learning. Radical innovation processes, while poorly understood, are closely linked to these concepts of learning – to asking and effectively addressing questions of "are we doing the right things?" and "how do we decide what is right?" Efficiency and performance will remain important as ways of ensuring that we are "doings things right," but the responses required for adaptation of our water, food and energy systems, of our urban form and processes will not be found in single-loop learning. Rather, they will require deeper, more radical forms of learning and change.

Innovation and Collaboration

So what do we know about the skills needed to drive processes of innovation, particularly radical innovation? As Tidd and Bessant (2004) note, little is known about these processes in general terms except that they are complex and difficult. We do know, however, that innovation processes are becoming more "open," with innovations occurring as a consequence of knowledge generated from collaborations across organizational boundaries (Chesbrough 2003), and consequently that collaborative skills are important. We also know that promoting and enabling collaboration between personnel across units within organizations, and between organizations is a key part of developing new opportunities as well as effectively and efficiently solving problems (Hansen and Oetinger 2001). And we know that effective collaboration, collaboration characterized by the creation of shared understandings of purpose, values and activity which yields benefits to the group as well as to individuals separately, is essential to group effectiveness (Head 2003). We also know that effective, as opposed to functional, collaboration tends to have effects like double-loop learning whereby collectively generated reflection and knowledge lead to more radical, status quo challenging action (Head 2003).

Finally, we know that many of the water-related problems facing the world are "wicked" in the sense of the phrase as originally coined by Rittel and Webber (1973). Such "wicked problems" can only be defined with respect to the sets of solutions that may be used to tackle them (e.g., economic, legislative, social/behavioral, technological etc.), and it is in the process of thinking through potential solutions that problem constructions emerge. One might reasonably ask: is the water-food-energy nexus primarily an efficiency of production or supply problem, an economic trade problem, a behavioral problem, or a waste problem? Deciding frames the problem. Radical innovation is therefore not a sufficient proscription for the kind of responses required. Rather there is a need for effective collaboration that leads to radical innovation in a way that is cognizant of inherent wickedness.

Here we consequently put forward the argument that in order to be able to stimulate and manage radical innovation and to address "wickedness," water professionals must develop the ability to critically and collaboratively synthesise the insights of multiple potential solution sets embodying multiple disciplinary, sectoral, and stakeholder perspectives.

Leadership and Innovation

Change is the focus also of the leadership literature, where the term leadership can be defined as a process of influence that involves three elements (Taylor et al. 2012 drawing on the work of Drath et al. 2008 and Ernst and Chrobot-Mason 2010). The first is setting a direction or shared vision, whether it be for a project, team

or organization. The second is aligning resources to that direction. Resources may include people, projects, tasks, or funds. The third element is building commitment among a group of people to achieve the vision, which usually involves motivating and inspiring others. Leadership can apply to radical or incremental innovation (as defined by Tidd and Bessant 2004) or change processes, and the vast leadership literature provides a rich source of evidence regarding the kinds of skills and behaviors associated with effective leadership (see Northouse 2010).

We argue that the capacity for effective leadership is one of the key components of a T-shaped water professional. We make this argument for three key reasons. First, leadership is needed to initiate and drive change, enable innovation (both incremental and radical), build shared visions for a more sustainable water future, and deliver these visions through aligning resources and building commitment to collective success. Second, specific forms of leadership are needed to address the complex (wicked), cross-boundary, and multi-stakeholder nature of challenges that commonly face the water industry. It is simply not enough to be a technical expert, or a good project manager. Third, social research in the water sector has clearly highlighted the critical role of different types of leaders, and networks of leaders in enabling transitions from traditional to more sustainable forms of water management (Brown and Clarke 2007; Meijerink and Huitema 2010; Taylor 2010).

Once we accept that water professionals need greater leadership capacity, the question becomes which leadership competencies are critical and how should these be strengthened? We suggest that care needs to be taken when identifying specific leadership competencies (e.g., bodies of knowledge and skills), given the broad range of leadership skills and the plethora of leadership theories, models and conceptual frameworks. Research into the leadership attributes of effective water leaders, as well as networks of water leaders, helps to identify key leadership competencies that could be enhanced through professional development programs. For example, within the International WaterCentre's Water Leadership Program we have used research to identify particular forms of leadership that are relevant, and then built educational curricula for these forms of leadership that draw from relevant leadership theory, models, and research. As one example, guidance on becoming a more effective project champion (emergent leader) draws from the "champion of innovation" literature (Howell 2005; Howell and Higgins 1990) as well as from research in the water sector (Brown and Clarke 2007; Taylor 2009; 2010).

Many of the forms of leadership that we know are relevant to water practitioners who wish to innovate, drive change, and advance more sustainable forms of water management have significant consequences for educational programs that aim to support such professionals. As just one example, consider the concept of "innovation/creative leadership" (see Horth and Buchner 2009, Mumford et al. 2002). An aspect of this form of leadership focuses on the leadership behaviors team leaders should use to foster creativity and innovation. It is highly relevant to many water practitioners. Mumford et al. (2002) developed a tripartite model of creative leadership to help understand this leadership role, as "leadership of creative people cannot be understood through the rote application of extant (traditional) [leadership] models" (p. 737). The first element of Mumford's model is "idea generation." When adopting this leadership style, the team leader facilitates conditions that are conducive to the generation of new ideas. They question the status quo, use creative problem-solving techniques, build bridges between people and organizations, provide people with freedom to pursue new ideas, foster group diversity, encourage open communication and build a culture that celebrates new ideas. The second element is "idea structuring." When engaging in this leadership style, the team leader provides detailed guidance to members on the technical and organizational merits of new ideas (i.e., specific feedback), clearly communicates expectations (e.g., goals), available resources and timeframes, and encourages integration between relevant projects. The final element is "idea promotion," where the team leader needs to gather support from their organization for innovative ideas or projects. They essentially act as a "champion of innovation" on behalf of the team, seeking official endorsement or funding to proceed with the initiative (e.g., deliver an innovative water management project).

There are several significant consequences of

Mumford et al. (2002) leadership model for water practitioners and educators. First, a very broad range of leadership skills are needed to successfully use the idea-generation, idea-structuring, and idea-promotion styles of leadership. Second, leaders need to be knowledgeable and self-aware, so they can consciously modify their leadership style depending on the needs of their team (e.g., switch from the idea generation to idea-structuring style). Third, when using the idea structuring style, Mumford et al. found that effective team leaders of highly creative teams have unusually high levels of technical knowledge. This knowledge is needed so they can understand new innovations and provide detailed feedback. For the T-shaped water professional who wants to effectively lead creative teams, this means that they need to have an in-depth knowledge of a particular discipline/issue, as well as a broader, general knowledge to identify opportunities for idea generation, collaboration, and integration.

Ethics, Values, Context, and Innovation

The ability to collaborate with professionals, and community members, who operate from different epistemological bases and perspectives is essential but not sufficient. Water professionals must be cognizant of, and act upon, the ethical dimension of their work. Why?

First, the concepts of ethics, personal values, and leadership are intertwined and inseparable. Clarifying personal values, communicating these to others, and acting in accordance with these values are the core steps to building credibility as a leader (Kouzes and Posner 2007). Personal values play a critical role in leadership emergence, motivation, the choice of behaviors in ambiguous contexts, the formation of organizational cultures, and the process of building shared visions for initiatives. They are so fundamental to leadership that they are often referred to as "the leaders compass." In addition, there is now a strong demand for more authentic leadership across society (see Northouse 2010). Authentic leaders are self-aware, transparent, value doing the right thing, and place meeting group needs above personal needs. Increasingly, leadership without a strong ethical foundation is seen as being socially unacceptable. Consequently, we argue that educational programs that aim to foster effective water practitioners who can engage in leadership should incorporate ethical and value-related components to their curricula.

Second, we must move beyond the heavily critiqued, values-free approach to management embodied by hard systems or operational research and modern management science (see critiques by Ackhoff 1979 and by Saul 1992). Flyberg (2001), using the distinctions of knowledge and case provided by Aristotle is his *Nichomachean Ethics*, argues that knowledge of how to wisely and ethically use scientific knowledge (episteme) and engineering knowledge (techne) is the most important form of knowledge. This knowledge is called phronesis and is key to avoiding disproportionate or unexpected negative impacts on different groups of people or other species here now, further into the future or elsewhere (see the sustainability framework described by Thiele 1999).

If one accepts that double-loop learning is a key process involved in radical innovation, then one must, by definition, also accept that the development and application of phronetic knowledge is central – for one can only answer the question "are we doing the right things?" through the application of an ethical framework. The work of Chris Argyris on organizational learning is clear on the role of double-loop learning in questioning and transforming existing values and power relations (Tosey et al. 2012).

The application of ethics to water management, or indeed, most other forms of inquiry and action can be guided simply by use of Flyvberg's (2001) four key questions:

1. Where are we going?
2. Is this desirable?
3. What should be done?
4. Who gains and who loses?

We consequently put forward the argument here that, the use of these questions as part of a regular reflective process in professional activity will help reveal the impacts of (planned) actions, and more fundamentally the role that the professional plays in shaping the world as a consequence of being part of a larger socio-technical system of activity. Such a reflective process will help underpin the double-loop learning necessary for radical innovation as well as informing ethical action.

A Proposal: The T-Shaped Water Professional

We have argued so far that the challenges of the 21st century will require professionals capable of engaging in and creating the conditions for collaborative, double and perhaps even triple-loop learning as a means of stimulating and driving radical innovation and coping with wickedness. We have also argued that leadership skills and behaviors will be required to drive the innovation process through influencing, but that the concept of leadership requires extension:

1. To include knowledge of the range of subjects that underpin water management and that effective leaders must be able to engage with conceptually to enable collaboration (and consequently learning and innovation).
2. Beyond even the above, to include the development of knowledge about how to integrate values and evidence within an ethical framework and as part of double-loop learning (phronesis).

How might one conceptualize such a professional, and use the conceptualization as the basis for the development and operation of education programs? Figure 2 presents a model of the kind of professional with the kinds of skills we have described over the course of this paper. The model is termed the T-shaped water professional and represents insights from a mixture of literatures. It is currently used as a basis for the professionally targeted, postgraduate integrated water management education programs run by the International WaterCentre, for whom the authors work, namely the Masters of Integrated

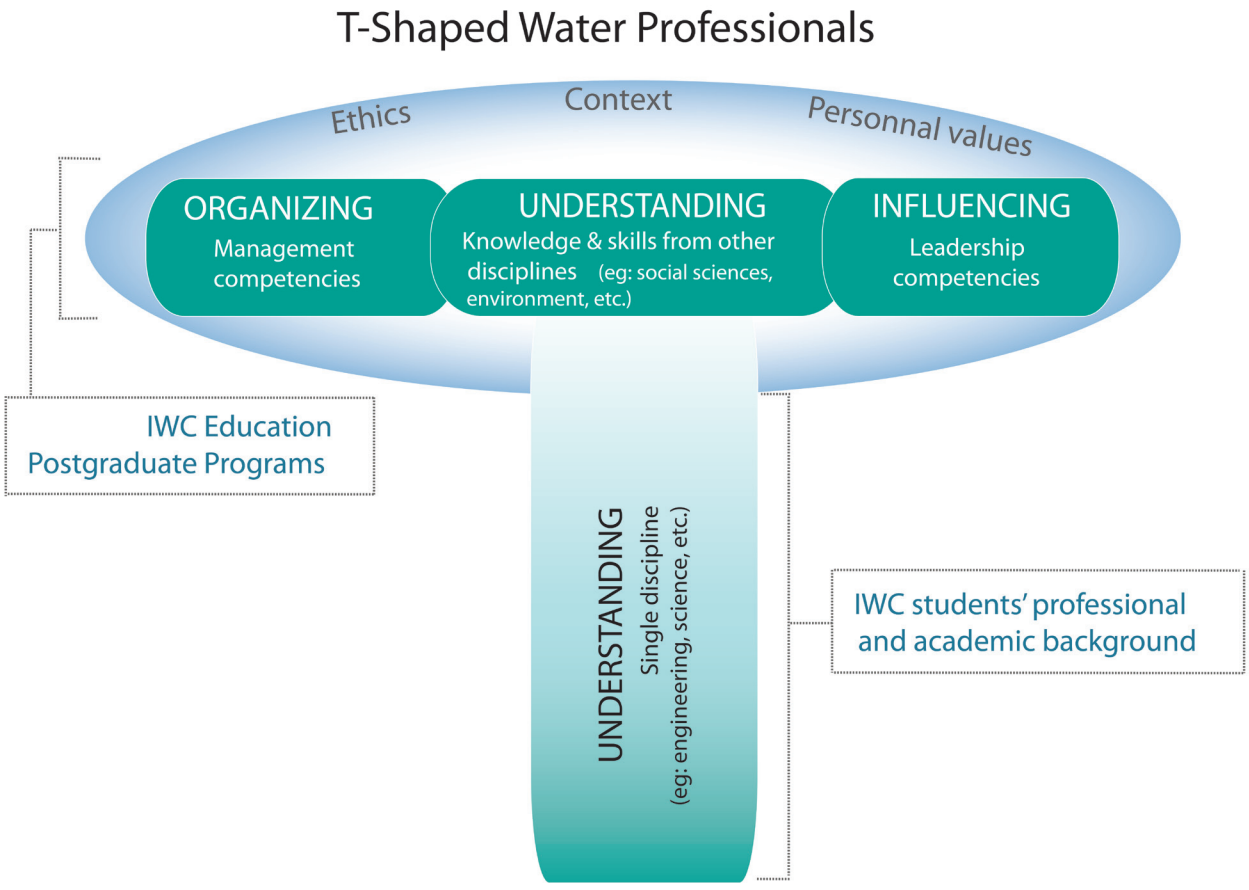


Figure 2. Conceptual model of a T-shaped water professional (used with permission from the International WaterCentre).

Water Management and the Water Leadership Programme. However, the model has scope for use beyond the confines of the IWC to guide the design of curricula for professional, post-graduate water management education more generally.

As noted in the introduction, the concept of the T-shaped manager or T-shaped professional has been documented elsewhere in relation to water management (Uhlenbrook and de Jong 2012) and even applied extensively within the context of large companies (Hansen and Von Oetinger 2001). We have framed the T-shaped water professional to share some of the same characteristics – deep functional or disciplinary knowledge (the vertical bar, or I part of the T) capped with a breadth of knowledge (the horizontal or cross-bar of the T) which represents the T-shaped water professional being able to operate across disciplinary, functional, or organizational boundaries with other professionals as part of collaboration, double-loop learning and innovation.

One would expect that a professional would normally develop a T-shape over time as a consequence of normal career development where technical specialists, for example, often gain management and leadership skills. The T-shaped water professional model is an attempt to characterize and structure what the cross-bar of skills and knowledge should be in light of the issues discussed about change and innovation throughout this paper. There are three core groups of skills and knowledge that have been identified from work in emergent leadership in the water sector (Taylor et al. 2011; 2012):

- Understanding – the mix of additional disciplinary and functional knowledge required to turn deep disciplinary or functional specialists into professionals able to collaborate across boundaries. In water this knowledge would include natural sciences (e.g., hydrology, ecology), social sciences (e.g., sociology, psychology, governance, economics) and engineering (e.g., process treatment, hydraulics).
- Organizing – the mix of management skills and knowledge that are essential for effective implementation of innovation, and for more general problem solving and team work within organizations. Examples include project management, systems thinking, and stakeholder analysis.
- Influencing – the set of behaviors and skills that are associated strongly with leadership as a process of influence. Examples include social networking, choosing appropriate influence tactics, and team leadership.

These sets of skills and knowledge are set within a broader framework that includes ethics and personal values (to reflect the importance of phronesis and self-reflection to innovation and sustainability) and context, for different organizational, governance, and cultural contexts will demand different skills and knowledge within each of the three core sets (Taylor et al. 2012).

Discussion

The way the T-shaped concept is put into practice by the IWC is partly by focussing on recruiting professionals – participants who already have a developed set of deep disciplinary and functional skills and knowledge (in effect a developed "I" shape by education and practice) and who are keen to broaden, to take on an emergent leadership role and to drive innovation (and probably have some form of T-shape to their skills and knowledge emerging already). While the idea of introducing deliberately T-shaped education programs at undergraduate level exists, at least for IT disciplines (Harris 2009), we argue here that deep disciplinary and functional knowledge is needed at that level. A different line is taken by Uhlenbrook and de Jong (2012), who argue that the growing complexity and scale of water management challenges requires that deliberately T-shaped approaches to education are introduced earlier, at the undergraduate level. Our response is that the team-building, collaborative and problem-based skill development this would entail are entirely appropriate, but that careful attention to developing depth of knowledge remains essential at the undergraduate level.

Two additional keys to building educational programs to help people to become T-shaped water professionals are research and flexibility. Research into effective water practitioners in a variety of

contexts can highlight key competencies that should be offered in educational programs that aim to enable T-shaped water professionals. For example, at the International WaterCentre, our Water Leadership Program focuses on building competencies linked to three key, non-executive water leadership roles (i.e., the team leader, enabling leader and project champion roles). These roles were identified through research into effective water leaders.

Choice and flexibility is also needed as everyone's professional work context is unique. While some competencies are likely to be needed by all water professionals (e.g., systems thinking and project management), others may only be needed in particular contexts (e.g., skills in policy development or influencing politicians). Programs are seeking to enable T-shaped water professionals need to provide flexibility so that water professionals can build a set of competencies that best meets their current and future professional needs.

Conclusions

In summary, we have critically argued:

- The set of global water, food, and energy challenges caused by 21st century demographic growth and change, and climate change are significant and require skills in radical and incremental innovation, and change management, to tackle effectively.
- Innovation is not well understood but is related to double-loop and triple-loop or Level III learning, all of which require effective collaboration.
- Consequently that collaborative skills and the ability to work across disciplinary and functional knowledge boundaries will be key for water professionals as part of stimulating radical innovation.
- But that being able to collaborate is not sufficient for double-loop learning – the ability to reflect upon the ethics of action and to integrate values and evidence is critical.
- The set of skills and knowledge required of water professionals in the 21st century can be characterized by the concept of a T-shaped water professional, and used to guide the curriculum of professionally focused, postgraduate education programs.
- Leadership as a broad set of competencies, is highly relevant to water professionals who recognize the need to initiate and drive change, including fostering creativity and innovation. As there are many forms of leadership and leadership competencies, we argue that educational programs that aim to boost the leadership capacity of water professionals (as part of their T-shape professional profile) should focus on those competencies that are known to be associated with effective water leaders. Context-sensitive research can help to identify such competencies.

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References

Argyris, C. and D.A. Schön. 1974. *Theory in Practice: Increasing Professional Effectiveness*. San Francisco, CA: Jossey-Bass.

Bateson, G. 1973. *Steps to an Ecology of Mind: Collected Essays in Anthropology, Psychiatry, Evolution and Epistemology*. Paladin, London.

Bokeno, R.M. 2003. The work of Chris Argyris as critical organization practice. *Journal of Organizational Change Management* 16(6): 633-649.

Boyer, H., T. Beatley, and P. Newman. 2009. *Resilient Cities, Responding to Peak Oil and Climate Change.* Washington DC: Island Press.

Brown, R. and J. Clarke. 2007. *Transition to Water Sensitive Urban Design: The story of Melbourne, Australia*. Melbourne, Victoria: Facility for Advancing Water Biofiltration and National Urban Water Governance Program, Monash University.

Brown, R. and M. Farrelly. 2009. Delivering sustainable urban water management: a review of the hurdles we face. *Water Science and Technology* 59(5): 839.

Chesbrough, H. 2012. Open Innovation, Where We've Been and Where We're Going. *Research-Technology-Management* July-August 20-27.

De La Salle, J. and M. Holland. 2010. *Agricultural Urbanism: Handbook for Building Sustainable Food Systems in 21st Century Cities*. Green Frigate Books, Manitoba, Canada.

Doppelt, B. 2003. *Leading Change Towards Sustainability. A Change-Management Guide for Business, Government and Civil Society*. Sheffield, England: Greenleaf Publishing.

Drath, W., S. McCauley, C. Palus, E. Van Velsor, P. O'Conner, and J. McGuire. 2008. Direction, alignment, commitment: Towards an integrative ontology of leadership. *The Leadership Quarterly* 19(6): 635-653.

Ernst, C. and D. Chrobot-Mason. 2010. *Boundary Spanning Leadership: Six Practices for Solving Problems, Driving Innovation, and Transforming Organizations.* New York, New York: McGraw-Hill.

Fagerberg, J. and B. Verspagen. 2009. Innovation studies – the emerging structure of a new scientific field. *Research Policy* 38: 218-233.

Flyvberg, B. 2001. *Making Social Science Matter: Why Social Enquiry Fails and How it Can Succeed Again*. Cambridge University Press.

Hansen, M.T. and B. von Oetinger. 2001. Introducing T-Shaped Managers, Knowledge Management's Next Generation. *Harvard Business Review* March: 107-116.

Harris, P. 2009. Help Wanted: "T-Shaped Skills to Meet 21st Century Needs." *Technology and Development* 63(9): 42-47.

Head, G. 2003. Effective collaboration: deep collaboration as an essential element of the learning process. *Journal of Educational Enquiry* 4(2): 47-62.

Horth, D. and D. Buchner. 2009. Innovation leadership: How to use innovation to lead effectively, work allow productively and drive results. Center for Creative Leadership, Greensborough, North Carolina.

Howell, J. 2005. The right stuff: Identifying and developing effective 'champions of innovation'. *Academy of Management Executive* 19(2): 108-119.

Howell, J. and C. Higgins 1990. Champions of technological innovation. *Administrative Science Quarterly* 35(1990): 317-341.

Jønsch-Clausen, T. and J. Fugl. 2001. Firming up the conceptual basis of integrated water resources management. *Water Resources Development* 17(4): 501-510.

Kouzes, J. and B. Posner. 2007. *The Leadership Challenge*. Fourth edition. San Francisco, California: Jossey-Bass.

Leach, M., J. Rockström, P. Raskin, I. Scoones, A.C. Stirling, A. Smith, J. Thompson, E. Millstone, A. Ely, E. Arond, C. Folke, and P. Olsson. 2012. Transforming innovation for sustainability. *Ecology and Society* 17(2): 11.

Leavitt, H.J. 1965. Applied organizational change in industry. In March, J.G. (Ed.) 1965. *Handbook of Organizations*. New York, Rand McNally.

Lenton, R. and M. Muller (Eds.) 2009. *Integrated Water Resources Management in Practice, Better Water Management for Development*. Earthscan, Washington.

Meijerink, S. and D. Huitema. 2010. Policy entrepreneurs and change strategies: Lessons from sixteen case studies of water transitions around the globe. *Ecology and Society* 15(2): 1-21.

Mumford, M., G. Scott, B. Gaddis, and J. Strange. 2002. Leading creative people: Orchestrating expertise and relationships. *The Leadership Quarterly* 13: 705-750.

Newman, P.W.G. 1999. Sustainability and cities: extending the urban metabolism model. *Landscape and Urban Planning* 44: 219-226.

Northouse, P. 2010. *Leadership Theory and Practice*. Fifth edition. London, England: Sage.

Prime Minister's Science, Energy and Innovation Council. 2010. *Challenges at Energy-Water-Carbon Intersections*. Prime Minister's Science, Engineering and Innovation Council. Canberra, Australia.

Rittel, H.W.J. and M.M. Webber. 1973. Dilemmas in a General Theory of Planning. *Policy Sciences* 4: 155-169.

Romme, A.G.L. and A. Van Witteloostuijn. 1999. Circular organizing and triple loop learning. *Journal of Organizational Change Management* 12(5): 439-454.

Saul, J.R. 1992. *Voltaire's Bastards, The Dictatorship of Reason in the West*. Vintage Books, New York.

Schepelmann, P., Y. Goossens, and A. Makipaa. 2010. *Towards Sustainable Development, Alternatives to GDP for measuring progress*. Wuppertal Institute for Climate, Environment & Energy, Germany.

Smith, A., A. Stirling, and F. Berkhout. 2005. The governance of sustainable socio-technical transitions. *Research Policy* 34 (10): 1491-1510.

Spiller M., B.S. McIntosh, R.A.F. Seaton, and P.J. Jeffrey. 2012. An organisational innovation perspective on change in water and wastewater systems - the implementation of the Water Framework Directive in England and Wales. *Urban Water Journal* 9(2): 113-128.

Spiller M., B.S. McIntosh, R.A.F. Seaton, and P.J. Jeffrey. 2013. Implementing Pollution Source Control – Learning from the Innovation Process in English and Welsh Water Companies. *Water Resources Management* 27(1): 75-94.

Taylor, A. 2009. Sustainable urban water management: Understanding and fostering champions of change. *Water Science & Technology* 59(5): 883-891.

Taylor, A. 2010. *Sustainable Urban Water Management: The Champion Phenomenon*. Ph.D. Thesis. Melbourne, Victoria: National Urban Water Governance Program, Monash University.

Taylor, A., C. Cocklin, R. Brown, and E. Wilson-Evered. 2011. An investigation of champion-driven leadership processes. *The Leadership Quarterly* 22(2): 412-433.

Taylor, A., C. Cocklin, and R. Brown. 2012. Fostering environmental champions: A process to build their capacity to drive change. *Journal of Environmental Management* 98: 84-97.

Thiele, L.P. 1999. *Environmentalism for a New Millenium, the Challenge of Co-evolution*. Oxford University Press, Oxford.

Thomas, A.D. and R.R. Ford. 2005. *The Crisis of Innovation in Water and Wastewater.* Edward Elgar Publishing Limited, UK.

Tidd, J. and J. Bessant. 2004. *Managing Innovation Case Studies: Developing an Organizational Culture That Facilitates Radical Innovation in a Mature Small to Medium-Sized Company: Emergent Findings*. John Wiley and Sons, Chichester. Available at: http://www.managing-innovation.com/case_studies/Cerulean.pdf.

Tosey, P., M. Visser, and M.N.K. Saunders. 2012. The origins and conceptualisations of 'triple-loop' learning: A critical review. *Management Learning* 43(3): 291-307.

Uhlenbrook, S. and E. de Jong. 2012. T-shaped competency profile for water professionals of the future. *Hydrology and Earth System Sciences* 16: 3,475-3,483.

UK Green Building Council and Zero Carbon Hub. 2010. Sustainable Community Infrastructure. London.

Van Vliet, B., H. Chappells, and E. Shove. 2005. *Infrastructures of Consumption.* London: Earthscan.

Walsh, C.J., A.H. Roy, J.W. Feminella, P. D. Cottingham, and P.M. Groffman. 2005. The urban stream syndrome: current knowledge and the search for a cure. *Journal of the North American Benthological Society* 24: 706-723.

World Economic Forum. 2011. *Water Security: The Water-Energy-Food-Climate Nexus*. Island Press, Washington.

World Economic Forum. 2012. Global Risks 2012, 7th Edition. World Economic Forum, Geneva. Available at: http://www3.weforum.org/docs/WEF_GlobalRisks_Report_2012.pdf.

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Popular Education for Water Sustainability: Three Lessons from Reflective Practice

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Abstract: Between them, the authors of this paper have over sixty years experience in water education working in primary and secondary schools, universities, field study centres, professional development programs; and with community, industry, and government groups, focusing on coastal zones and catchments. Over the last three years, they have undertaken a systematic process of personal and dialogic reflection and deliberation on this experience, particularly in the area of popular education. This paper presents three key water education lessons gained from this iterative process and provides examples to justify the sagacity of this choice. First and foremost, popular water educators really need to know their participants, what is important to them, why, and what they know already. Second, popular water educators should give their participants an opportunity to share with others what they have learned about water. Lastly, metaphorically speaking, popular educators need to focus their practice on the head, the heart, and the hands. Knowledge, emotion, and action are dialectically interrelated. Integrating them in popular water education is a challenging yet satisfying task that can have significant outcomes.

Keywords: *Popular education, community outreach, watershed management*

This paper focuses on the role of popular education in integrated water management. It outlines three lessons gained from practice. Education is one of a range of tools that water resources managers can use to improve the sustainability of ways people interact with water, waterways, catchments and coastal zones. Over the last thirty years, many different tools have been used in an effort to improve the sustainability of water management, including legislation and regulation, market-based instruments, marketing and communication programs, and improved technology and end-of-pipe solutions. Governments have introduced environmental management legislation (e.g., Queensland Government 1994; Queensland Government 2000). Economists have advocated innovative ways of valuing our ecosystems and the services they provide us (e.g., Costanza et al. 1987). Marketing and communication experts have communicated messages tailored to specific audiences (e.g., Kennedy 2010). Researchers have discovered more about the actual nature of water problems and opportunities that confront us and how best to manage them (e.g., eWater Cooperative Research Centre 2012). While each of these groups of tools undoubtedly plays a part in sustainable water management, it has been the experience of the authors and others (e.g., Cosgrove, Evans, and Yancken 1994) that a thoughtfully developed, context-specific mix of tools is necessary, if water management is to be improved in any given situation.

So education, while not the answer, is definitely part of the answer.

An Education Dialogue and Critical Reflections on Practice

Both authors have worked as educators at key times in their careers. Bill was born, raised and educated in the United States and trained in marine science. Peter is Australian; his rather eclectic academic background has spanned land use management, ecology, education, and social science. Bill has worked primarily in research and university teaching. Peter has worked as a researcher, but has spent much of his professional career working as a

teacher in field, community, school, and university settings. Peter has also spent some fifteen years working as a volunteer and government-employed extension officer supporting community-based natural resource management groups working in catchment management and Landcare. They met in 1997 when Peter visited Bill at his laboratories at The University of Queensland seeking causes of a cyanobacterial bloom of *Lyngbya majuscula* that was infesting northern Moreton Bay, south-east Queensland. Peter was working on a state government catchment management initiative with commercial fishers. The commercial fishers had been forced to fish in the Lyngbya bloom area after being excluded by new government regulations from fishing in nearby Pumicestone Passage.

Bill and Peter found they held similar ideas about the importance of involving stakeholders, participants who really had something to gain or lose, in learning about the cyanobacterial bloom and how best to manage it. Despite their different backgrounds, they both saw education as important, particularly in terms of them learning together with stakeholders. Further on in their careers, Bill and Peter have had the opportunity to reflect systematically on their practice, including on this case study. The popular education lessons presented in this paper form part of the findings of a larger reflective practice project they have undertaken over the last three years. The methodology used to derive this publication and this paper is presented below, as are two concepts – reflective practice and popular education.

Initially, Bill and Peter had a series of discussions on general topics that related to their work in catchment and coastal management. They told relevant stories from their varied experience, asking each other questions and seeking points of commonality and difference as to what they had done, why it was important to them and what they learned from that experience. They initially talked using Skype, with conversations lasting two to three hours. On several subsequent occasions they talked face-to-face, looking and probing more deeply into what they have learned in their working lives to date and seeking lessons that could guide them into the future.

Peter and Bill analyzed texts of their conversations, following the advice of Schön (1983) reflecting on their practice in the hope that the outputs of this reflection would not only guide their future practice, but that the process and the outcomes may also be of use to others. They coded transcripts systematically, looking for themes and using these outputs to inform further dialogue. This interactive, dialogic process was punctuated by considerable periods in which the authors were apart, allowing time for both individual reflection and subsequent deliberation and agreement on key lessons when authors came together to discuss their individual analyses (Miles and Huberman 1994). This paper presents key lessons they have gained in popular education for water sustainability.

Reflective Practice

Osterman (1990) sees reflective practice as an individual task of reflecting on one's own work and experiences so that the individual may improve themselves in their area of expertise. Forester (1999) talks of deliberative practice and considers this as an extension of reflective practice in which practitioners work, reflect, and learn collectively with others. In a sense, the work presented here has been both reflective and deliberative in that the authors have reflected individually and then deliberated on what they have learned and how they can further improve their practice as a result of this learning. For brevity, the term reflective practice is used to summarize this process. The authors take solace from the work of Schön (1983), who claims that competent practitioners in any field usually know more than they can say. They recognize that, over time, the origins of this knowledge can be difficult to determine. For example, we may learn things incidentally "on the job," such as how to use PowerPoint or write a consultancy report, and not view acquisition of these skills as "learning." However, these may be just as important as lessons from our academic studies (Schön 1983). The authors both value and enjoy working, deliberating, and learning collaboratively with stakeholders. This collaborative learning becomes a valuable source of knowledge and skill.

For example, in the *Lyngbya majuscula* case study they both learned much from the commercial fishers. These fishers had been disempowered. Their previous fishing grounds in Pumicestone Passage had been closed by the government and they found

themselves forced to make a living fishing in an unhealthy and unproductive cyanobacterial (blue green algal) bloom in adjacent Northern Moreton Bay. The work undertaken with these fishers bears many of the hallmarks of popular education, and it is to this topic that the discussion now turns.

Popular Education

Popular education differs from formal education one finds in institutions such as schools, universities and colleges. It focuses more strongly on the direct needs of the community (Whelan 2005), and seeks to empower those who may be socially, economically, or politically marginalized so that they may take control of their own learning and overcome the aspects of their situation that have caused this marginalization (Hale 2005). It is based on the methodology of education for critical consciousness first described by South American educator, Paulo Freire (1993), and has its origins in Marxist ideology and class analysis. It is conceptually aligned with critical social science which aims to enlighten, empower, and emancipate participants (Fay 1987). Popular education is a collective process in which, unlike formal education, the roles of teacher and learner are not well defined, as all participants at various times will be both a teacher and a student.

These popular education characteristics typify the work undertaken with the fishers. They had been politically marginalized in their dealings with government, and their new fishing grounds were detrimental to them economically, and in terms of their health (Savige 2012). The cyanobacterial blooms that occurred contained carcinogens. The blooms also caused skin rashes, and eye and breathing problems (Osborne, Webb, and Shaw 2001).

Bill's role was initially as a researcher and a teacher as he sought to find out more about the bloom, what caused it to grow and to share this knowledge with fishers and other interested folk. Peter was more the facilitator, focusing people's attention on the issue and bringing different parties together. This changed over time, as Bill and Peter learned much from the fishers who were excellent natural historians. The commercial fishers were close and accurate observers of nature. They had to be in order to make a living. Working together, Bill, Peter, and the fishers began to use the information they all gained about the bloom to advocate for local fishers. Research funding was gained from all levels of government, and a research team and steering committee were established. Media coverage of the bloom was widespread. Local government took steps to ensure that community health issues were managed by closing and cleaning beaches when blooms were prevalent. What occurred focused strongly on the direct needs of local people. The process was nonformal and informal, yet educational – all involved acted as both teachers and learners, at various times. The lessons gained were empowering and "of the people." This new knowledge and the support of the researchers empowered the fishers to advocate more strongly for their situation and the resolution of the economic and health problems they faced.

Education may contest or reinforce the status quo (Giroux 2001). Popular education, due to its change-oriented nature, seeks to address inequities and contest the institutions, cultural norms, or social and political systems that support these inequities, or allow them to exist. The Lyngbya case study is an example of both popular and informal education. Bill and Peter applied the method described above to this case study to reveal three key lessons that may be relevant for other popular educators working in nonformal settings. These are: know your participants; recognize that all involved are both teachers and learners; and focus on topics and activities that involve the head (thinking), the heart (emotions – music, art, dance), and the hands (practical activities) as means for participants to learn and use knowledge gained to address power inequities, or other problems that face them. These lessons are discussed below, using examples from the Lyngbya case study.

Three Lessons

Know Your Participants

As mentioned earlier, popular education focuses on the direct needs of the community and seeks to empower those, such as the fishers in the Lyngbya case study, who may be politically, socially, or economically marginalized (Hale 2005; Whelan 2005). As popular educators, the authors found it important to know their participants. This may seem

self-evident, so such a statement deserves some justification. Specifically, they found it important to know how the fishers defined (or "problematized") whatever had lead to their marginalization and how it affected them, others, and their surroundings; what was important to them in terms of the problem and why; what they knew already about the problem and what else they felt they may need to know; and what actions (if any) they felt should be taken to resolve this problem. These activities involved "walking in each other's shoes," as much as possible. Trust was also an important factor. Without trust, relationships falter and learning and action are impossible. Table 1 sets out some questions that may help to guide this reflection and learning and link them with key factors that help to describe the case study context. These questions and key context factors have been derived from the larger reflective project in which the authors are involved.

Space limitations preclude responding to all of the above questions in relation to this specific case study. The following discussion touches on five factors – knowledge, resources, empowerment, emotions, and equity.

In terms of knowledge, Bill spent a great deal of time on the water with fishers studying the bloom, in meetings and socially. He learned that the fishers were excellent observers of nature and seasonal, spatial, and other changes that were occurring in the marine ecosystem in which they were fishing. With the fishers' help Bill set about organizing needed resources and engaged the media to raise the public profile of this huge cyanobacterial bloom. They gained $AUD 600,000 in funding and in-kind support from political and departmental leaders in local, state, and federal government for urgent research to be undertaken to look at causes and management of the bloom. This was very empowering for the fishers.

Bill also came to understand emotional and equity issues relating to the bloom – whether the fishers thought what was happening was fair and how they felt. Over time cordial, trusting relationships developed between academics and fishers that helped to expose these aspects. Bill's wife, algologist Dr. Judy O'Neil, was part of the research team. Bill comments, "Judy was talking to the wife of one of the fishers. She explained that they were thinking of enrolling the kids in school next year and wondering, given the loss in catches due to the bloom, whether they would have the money to pay for tuition. What did Judy think they should do?" He found himself contrasting the worry and angst of the fisher's wife, against the demeanor of prospective researchers who were contacting him about their possible involvement in the Lyngbya research; some of whom he felt were simply seeking funding for their "pet" project, rather than focusing on really solving an environmental problem that fishers viewed as unfairly impacting on the lives of their families. Such conversations helped Bill develop greater empathy for the fishers and their plight. It did not mean that he became less objective in his Lyngbya research, but that he developed very similar motivations for solving the bloom problem as those of the fishers and their families.

Research undertaken as a result of Bill and the fishers' labors has discovered the causes of the Northern Moreton Bay Lyngbya bloom, and efforts have been undertaken to address them. Causes include "the presence of bio-available nutrients including iron, phosphorus, and nitrogen; dissolved organic matter; and favorable light, salinity and temperature conditions in the environment" (Queensland Government 2012). A Lyngbya Management Strategy has been developed, listing "agreed management actions for addressing the mitigation, investigation and catchment protection issues associated with Lyngbya blooms in Moreton Bay coastal waters, particularly in northern Deception Bay" (Moreton Bay Catchment and Waterways Partnership 2002: ii). However, due perhaps to the scale of the problem, at the time of writing, blooms are still occurring (Savige 2012).

The questions listed in Table 1 have been gained from an analysis of a wide variety of popular education examples in which the authors have been involved. Responding to them also helps to shed considerable light on this particular example. Being an effective popular educator involves knowing your participants very well and allowing them to also know you, not just as a researcher or teacher, but as a person. It is indeed important to walk in each other's shoes. Participants have much to learn from each other, as discussed below.

Table 1. Questions and key context factors to guide reflection.

Questions	Key context factors
What do participants know?	Knowledge
What do participants believe?	Beliefs
How much do participants care?	Emotions
Do participants think what is happening is fair? Why?	Equity
Do participants agree on the nature of the problem? What else might they need to know?	Problem consensus
Do participants feel able to act? Why?	Empowerment
Do participants agree on what needs to be done?	Action consensus
Do participants have what is needed to solve the problem? What else may they need?	Resources

Teachers and Learners

This lesson follows on from the first question stated in Table 1 – in terms of knowledge what do participants know? Many participants want to share with others what they know about the problem at hand. Our job as educators is to provide this opportunity. At various times participants take on different roles as "teachers" and "learners." However, for popular education to be effective, we need to learn together. Many participants want to share with others. We all need the opportunity both to teach and learn about what is important to us.

Bill was very keen to learn as much as he could about the Lyngbya blooms. Typically, there are several ways to do this including library research, literature reviews, communicating with other academic experts, and undertaking laboratory and field research. Bill chose an additional path. He decided to learn what he could from the fishers. They were the "on-water" (rather than "on-ground") experts on this particular Lyngbya bloom. Bill took a relationship-based rather than formal approach to do this. He went out on the water to inspect the bloom with them. Notably, he went in their boats. This was important both symbolically and practically. In terms of power, they were the captains. They were in charge. They were the teachers. Significantly, at another time, he went to the local bowls club with the fishers. They shared food and drank beer. The fishers became the teachers and Bill the student. The fishers were "at home," in their own environment. Bill and the fishers became co-researchers, learning together and freely sharing and critiquing what they were learning about the bloom. In this example, power was redistributed and shared within the researcher-fisher relationship. They developed a common, shared motivation. It became obvious to all involved that Bill was not just there to write another research paper or score another grant to further his career. He wanted to manage the bloom, to control it so that the fishers could still make a living fishing in the area (Savige 2012). Like Freire (1993), Bill felt that research grounded in local understanding, consistent with local motivations and involved those affected by research outcomes as active co-researchers and co-learners, had more chance of success. As mentioned earlier, sharing motivation with the fishers involved sharing emotion – for example, realizing that poor fish catches result in little income and an inability to provide things like school fees for those you love. Bill and Peter contend (with others) that our emotional state impacts on how and what we learn, and what we do as a consequence (Pedler 2011; Pekrun 1992). The following section uses the Lyngbya case study to explore the relationship between learning, emotion, and action.

Head, Heart, and Hands

"Head," "heart," and "hands" – thought, emotion, and action may be thought of as being dialectically (i.e., interactively) related. Thinking situated around such dialectical relationships has proven useful in counseling and community building (Kelly and Sewell 1988). The authors have also found it very useful in terms of popular and other forms of education. In the Lyngbya case study, the authors recognized that it was not useful, in fact impossible, for the fishers to compartmentalize their thinking, so that they thought "unemotionally" about the Lyngbya bloom and its impact on their lives. Emotion gives meaning. Emotion gives motivation. Emotion can drive people to learn and to act. While the fishers were understandably emotional and quite motivated to discover the causes of the Lyngbya bloom and to remedy the situation, the authors found that the rest of the local community, including local and state government decision-makers, were often disinterested.

Through the local catchment association, the fishers put out a series of media releases about the bloom (Savige 2012). These received mixed responses from community members, with several people being very critical of the catchment association issuing media releases before long weekends. For example, the owner of a fast food shop on Bribie Island rang one of the fishers to tell him he didn't like him talking about the bloom in the paper. He felt that telling people about the bloom and working out how to manage its causes were important, but something that should not be done now, especially with the long weekend coming up. "We will lose trade" (Savige 2012)! He was not alone, real estate agents and accommodation business people also berated the catchment association president for going public about the bloom. Thought, emotion, and action can be linked in different ways and lead to different outcomes.

In response to this community feedback, Peter decided to implement a community education program. He sought to complement the research and popular education activities that Bill was leading and the catchment association media campaign. He wanted to make learning about the bloom, its causes, and the importance of sea grass meadows in coastal marine systems fun – not emotionally or economically threatening. So he devised a series of music and cartoon characters to convey these messages. These were pitched at young people, six to eight years old, the idea being that this would not be threatening or controversial. Adults were an important secondary audience. So, Doug the Dugong, and the Dugong Rock were born. Music from the Dugong Rock CD can be downloaded from the Healthy Waterways web site, see http://www.healthywaterways.org/HealthyWaterways/Resources/CommunityServiceAnnouncement.aspx. On Dugong Rock, Doug sings:

I'm Doug, I'm a dugong and I live in the bay
For years there man it's been OK
You really gotta' dig the Dugong scene
We eat sea grass, sweet and green
But the waters goin' muddy
The light is dim
There's not much sea grass
The future's grim
And all I want to do is the Dugong Rock!

Doug's song contains key messages about sea grass and managing coastal ecosystems. Figure 1 shows Doug the Dugong as a cartoon character. He figured in a coloring competition in the local paper, the Near North Coast News, with Dugong Rock CDs for prizes. Doug the Dugong developed a public profile. His character has had longevity. He lives on from the time of this work (1997 to 2000) to today and can be heard on the soundtracks of current videos on YouTube. In 2003, Dugong Rock – The Musical played at the



Figure 1. Doug the Dugong – a cartoon character.

Woodford Folk Festival at the children's part of the festival, as well as at other locations around southeast Queensland.

Over time, with the help of the media, school and other public education activities relating to research, such as those outlined above, public awareness of Lyngbya blooms in Moreton Bay has risen. While pre-surveys and post-surveys of the impact of these activities on general levels of public awareness are not available, a current google search (25 May 2012) using the key terms – *Lyngbya majuscula* and Moreton Bay, revealed 6,090 results. A google search of the phrase "Doug the Dugong" revealed 160 results, with a YouTube search using "Dugong Rock" revealing the posting of 20 videos with a total of 14,656 hits. Interestingly, others have also thought it useful to adopt a similar approach with the Burnett-Mary Regional Group, even going to the extent of purchasing an $8,000 human-size dugong suit so they could undertake similar types of activities in Hervey Bay (see www.bmrg.org.au). This life-size walking dugong figures in two video clips and a community service announcement about Hervey Bay and associated stream catchments (Smith 2012). This is an example of popular education and community education finding ways to focus, motivate and energize participants in what Freire (1993) terms "conscientization," "knowing reality in order to better transform it" (Lather 1986: 67). The Lyngbya case study highlights that knowledge, emotion, and action are linked in ways that can be both positive and negative. The work of the Burnett-Mary Regional Group lends validity to this assertion. Being aware of this and consciously linking knowledge, emotion, and action can greatly help popular educators to be effective in their work.

In Conclusion

This paper uses the experiences of the authors, and the work of others, to reflect on popular education for water sustainability using a case study involving research, education, and community action on a *Lyngbya majuscula* bloom in northern Moreton Bay, southeast Queensland, Australia. The authors have undertaken a process of systematic personal and dialogic reflection and deliberation on this case study, to reveal three key lessons in terms of popular education. First, know your participants. Walk in their shoes. While this may appear self-evident, reflection and action on this point are fundamental to all educational activity. Such reflection should focus on the following context factors: knowledge, beliefs, emotions, equity, problem consensus (whether participants define the problem in the same way), empowerment, action consensus (whether participants agree on what action needs to be taken to resolve the problem), resources, and technical capacity. Second, when it comes to working as popular educators, we are all learners. We are all teachers. We need to learn from each other and evaluate knowledge and the purpose to which it should be put by working together. Lyngbya blooms are complex. Understanding and managing such blooms are complex activities. No one will know everything about such an occurrence, and people will perceive the impact of such a bloom upon their lives and their surroundings in different ways. It is only by working together that we can paint a rich picture to inform action. Finally, in all this there is an important place for emotion. What is important to our hearts, will impact our thoughts and knowledge, and what action we take to remedy our situation. We should not ignore the fact that knowledge, emotion, and action are dialectically related. As popular educators we have much to gain from sharing what is in our hearts with others.

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References

Cosgrove, L., D. Evans, and D. Yancken (Eds.) 1994. *Restoring the Land: Environmental Values, Knowledge, and Action*. Melbourne University Press, Melbourne.

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton, and M. van den Belt. 1987. The Value of the World's Ecosystem Services and Natural Capital. *Nature* 387: 253-260.

eWater CRC. 2012. *eWater Cooperative Research Centre: Evolving Water Management*. Available at: www.ewater.com.au.

Fay, B. 1987. *Critical Social Science: Liberation and Its Limit.* Polity Press, Cambridge.

Forester, J.F. 1999. *The Deliberative Practitioner: Encouraging Participatory Planning Processes*. MIT Press, London.

Freire, P. 1993. *Pedagogy of the Oppressed*, (2nd edition). Continuum Publishing Group, New York.

Giroux, H.A. 2001. *Theory and resistance in education: towards a pedagogy for the opposition*. Greenwood Publishing Group, Westport, Connecticut.

Hale, R. 2005. What is popular education anyway? *The Popular Education News*. Available at: popednews.org/newsletters/definitions.html on 13/06/12.

Huberman, A.M. and M.B. Miles. 1998. Data Analysis and Management Methods. In Denzin, N. and Y. Lincoln (Eds.) *Collecting and Interpreting Qualitative Materials*. Sage Publications, Thousand Oaks, CA.

Kelly, A. and S. Sewell, 1988, *With Head and Hand: Dimensions of Community Building*, Boolarong Publications, Brisbane.

Kennedy, A. 2010. Using Community-Based Social Marketing Techniques to Enhance Environmental Regulation. *Sustainability* 2(4): 1138-1160.

Lather, P. 1986. Issues of Validity in Openly Ideological Research: Between a Rock and a Soft Place. *Interchange* 17(4): 63-84.

Miles, M.B. and A.M. Huberman, 1994. *Qualitative Data Analysis: an Extended Source Book*, Sage Publications, Thousand Oaks.

Moreton Bay Catchment and Waterways Partnership. 2002. *Lyngbya Management Strategy*. Available at: http://www.healthywaterways.org/TheStrategy/ActionPlanLinks.aspx.

Osborne, N.J.T., P.M. Webb, and G.R. Shaw. 2001. The toxins of *Lyngbya majuscula* and their human and ecological health effects. *Environment International* 27(5): 381-392.

Osterman, K.F. 1990. Reflective Practice: A New Agenda for Education. *Education and Urban Society* 22(2): 133-152.

Pedler, M. 2011. *Action Learning in Practice*, Gower Publishing Limited, Burlington, Vermont.

Pekrun, R. 1992. The impact of emotions on learning and achievement: Towards a theory of cognitive/motivational mediators. *Applied Psychology* 41(4): 359-376.

Queensland Government. 1994. Environmental Protection Act, Queensland Government, Brisbane. Available at: http://www.legislation.qld.gov.au/legisltn/current/e/envprota94.pdf on 20/10/11.

Queensland Government. 2000. Water Act, Queensland Government, Brisbane. Available at: http://www.legislation.qld.gov.au/legisltn/current/w/watera00.pdf.

Queensland Government. 2012. Lyngbya, Queensland Government, Brisbane. Available at: http://www.derm.qld.gov.au/environmental_management/coast_and_oceans/marine_habitats/lyngbya_updates/index.html#causes_of_lyngbya_blooms.

Savige, G. (Bribie Island Commercial Fisher), in discussion with author, 2012.

Schön, D.A. 1983. *The Reflective Practitioner: How Professionals Think in Action*. Basic Books Inc Publishers, New York.

Whelan, J.M. 2005. Popular Education for the Environment: Building Interest in the Educational Dimension of Social Action. *Australian Journal of Environmental Education* 21: 117-128.

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Studying Nature *In Situ*: Immersive Education for Better Integrated Water Management

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Abstract: The term immersive education is currently used in two educational areas – language education, which involves students being totally immersed in a language and its culture; and virtual education, where teachers use computers and simulation games to immerse learners in a virtual, computer-generated environment that mimics a real-world environment and allows learners to interact with it. This paper uses examples from university teaching practices in marine studies and coastal zone management to make a case for a third definition for immersive education in tertiary settings – educating water managers by immersing and guiding them through real-world situations that involve understanding and managing water, biodiversity, catchments, and people, and the interactions between them. Immersive education of this third kind, and traditional tertiary education approaches such as lectures and demonstrations, are compared, and the advantages of immersive education are discussed. The examples from practice and discussion presented show immersive education as being experiential and real, process-driven, trans-disciplinary, collaborative, participatory, and active, encouraging critical thinking and a renegotiation of power in relationships between participants. Such immersive education develops passion and persuasive capacity in students, providing personal experiences that are memorable and potentially life-changing. Challenges to immersive education in tertiary education, including lack of finances, teacher burn-out, safety concerns, and inertia to maintain the status quo of traditional education, are highlighted, as are ways to overcome these.

Keywords: *Immersive education, experiential teaching, trans-disciplinary*

Louis Agassiz (1807-1873) declared, "Study nature, not books," on a sign at the entrance to his summer field course on Penikese Island off Cape Cod, Massachusetts, in the 1870's. Agassiz was a Swiss geologist who had correctly interpreted the impact of continental glaciers in forming the landscapes of northern Europe and North America. Agassiz emigrated to the U.S. and set up a field school that ran for several years on a small remote island until his death in 1873 (Wilder 1898). This course and teaching style were emulated by the Marine Biological Laboratory, set up in nearby Woods Hole in 1888. The Marine Biological Laboratory, the second oldest marine lab in the world, developed immersive summer courses and went on to create one of the world's premier biological libraries, which ironically, is appropriately where the sign now resides (Addante 2009).

Agassiz was renowned for starting his course by placing a whole fish in front of each student and asking them to draw and interpret what they could about the fish. When the students wanted to start dissecting the fish or doing experiments, Agassiz said to just leave the fish intact and observe. He then informed them that this was a half day exercise, and it would take a while for the students to realize that they needed to begin using their eyes and their brain. Agassiz deliberately was teaching them to look, really look at the fish, and begin thinking about how the fish sensed the environment, how it moved through the water, and how it was put together. This exercise got the students to make detailed drawings and sharpen their observational skills (Anon (a) 1879).

What can we learn from Agassiz's adage "Study nature, not books" from the nineteenth century? The progressive era of education (1917-1957) saw educators move away from experiential education to methods that were deemed more efficient such

as lectures, text books, and demonstrations (Tolley 1994). With the rapid growth of the natural sciences literature in the form of scholarly journals and books, and the explosion of sensors that can stream data directly to the laboratory, it may be argued that such "progressive" ideas should still hold sway. Significantly, the study of nature is increasingly linked with the study and management of land, water, and human systems. What can we learn about managing water by immersing ourselves in the real world? Why not just send students to online literature and the computer to download and interpret data or play simulation games? This paper makes a case for immersive education as a way to learn about and better manage water, the things that live in it, and the way that we interact with it and the surrounding landscape. From the management of coastal zones to integrated water management more generally, we need to create real, participatory, collaborative, trans-disciplinary learning experiences in which students study nature, land, water and human systems and the ways we might manage the interactions between them in situ, not from behind a computer screen.

Immersive Education

The term "immersive education" is currently used in two ways. The first is in language education. Language educators have long realized that the most powerful way to teach a second language is to immerse students in situations where that language is the sole communication medium for daily living and learning. The culture associated with that language becomes the dominant culture of the educational process (Cummins 1998).

The second use of "immersive education" relates to the development and use of virtual realities and game-based learning systems for educational purposes (e.g., Immersive Education Initiative 2012).

This paper proposes a third use for the term, arguing that learning about land, water, biodiversity and their management is a task best undertaken *in situ*, immersing the learning process in the setting that is the actual focus of management.

We contend that this conceptualization of immersive education has utility in terms of teaching about water – managing water more sustainably by understanding and managing land, water, the living things that live in and depend upon water for life, human systems, and the interactions between them. In the associated area of environmental education, Lucas (1979) wrote of it having essentially three foci – being about, in, and for the environment. We characterize immersive education as emphasizing the second of these three foci, being immersed in the environment, leading participants to learn more about that particular topic and them also becoming advocates for issues of sustainability relating to that topic. Students and teachers become active participants in real situations. Their learning is experiential. They collaborate. Their learning involves many disciplines. The term "immersion" is metaphorically appealing when we think of learning about water in this way. It may also be a useful educational vehicle in other settings.

In our experience, immersive education can mirror many of the characteristics of popular or participatory education, as described by Paulo Freire (1993). This is particularly true in relation to renegotiation of power relations between teacher and student and the development of a critical consciousness. In this model, students do not accept information at face value, but, like the students examining the fish in Agassiz's laboratory classes, examine what they learn about water more deeply, from diverse points of view, and through a range of disciplinary lenses to detect any factors which may detract from or add to the authenticity of their findings.

The authors have over sixty years of combined experience in water education in formal and nonformal settings. In terms of formal education, this experience ranges from teaching in primary schools, and outdoor and environmental education centers, through to secondary schools and universities. Topics taught have included biology and marine botany, and broader subjects such as marine studies and coastal zone management, through to secondary school environmental education and a post-graduate program in

integrated water resource management. Based on this experiential foundation, this paper compares traditional classroom teaching with immersive education, discusses advantages of an immersive approach, and proposes ways to overcome impediments to its implementation. Immersive education is defined based on aspects of the marine studies and coastal zone management education examples that follow. Finally, the paper proposes that immersive education may have use in many areas of water education from disciplinary-based water topics through to broader, more encompassing areas such as integrated water management, as this field is portrayed in the literature (e.g., Biswas 2004; Ferreyra and Beard 2007; Global Water Partnership 2012; Rahaman and Varis 2005). While immersive education may also have a place in nonformal water education and management settings, this is not the focus of what follows.

Comparing Traditional Classroom Teaching and Immersive Education

The traditional classroom setting has a teacher at the front of the room using a chalkboard for illustrations and the students dutifully taking notes as the teacher imparts knowledge. The chalkboards have been largely replaced with various technologies that serve to bring even more knowledge to the students, who can passively watch the "show." The following comparisons can be made between traditional classroom teaching and immersive education.

Traditional classroom teaching is content-driven. The subject matter is presented in a series of lectures. Immersive education is process-driven. Students learn how to do science. Traditional classroom teaching is broken up into disciplines (e.g., chemistry, biology, physics, geology) and content delivered accordingly. Immersive education is topic-driven and multi-disciplinary, as studying integrated water management inherently involves crossing the disciplinary boundaries. Over the last thirty years, while they may not be labeled as such, examples of immersive education can be found in many areas of higher education, particularly those where solutions to problems are not readily found within a single disciplinary domain and field settings that allow for immersion are accessible to educators. Examples include health, engineering, and environmental science (Ashford 2004; Gilbert 2005; Jacobsen 1990). Looking at what is in front of us in a field setting, rather than content from a single discipline, can turn teaching and learning on its head. In Bill's teaching he would often turn over a piece of coral rubble and ask students to identify which kingdom the encrusting organisms belonged. Sponges, tunicates, and algae can be difficult to distinguish, or which process had formed the rubble itself. Botany, zoology, and geology quickly become inter-twined with epiphytic algal succession and the nutrient sources of coral lagoon eutrophication processes.

Traditional classroom teaching has the teacher at the front of the room as the focal point. Immersive education has the teacher rotating between student groups, and at the end of the course, it is the students in front of the class. Power relationships between teacher and students are re-negotiated. Learning becomes participatory with students sharing responsibility for both teaching and their own learning (Freire 1993). Traditional classroom teaching ultimately is a forgettable experience. Immersive, experiential learning is truly unforgettable. Bill often says, "Put me in front of a classroom, and both the students and I will quickly forget what I said in class, but give me a student for several weeks on a ship or a field station and I will change their lives forever, and enjoy myself in the process."

Immersive education is experiential. Science being conducted by students is "real," not an exercise with predetermined answers. The students are doing science, not studying it. Before Bill's first voyage aboard a tall ship as Chief Scientist as part of the Sea Semester, based in Woods Hole, Massachusetts, he kept badgering the more experienced scientists about how he would be able to recognize the major oceanographic provinces as they transited the North Atlantic Ocean. Bill was worried that they would sail right over Georges Bank, through the Gulf Stream and into the Sargasso Sea before noticing any changes. His colleagues kept saying, "Oh, don't worry. You'll know when you get to the Gulf Stream." He was not

satisfied with their answer and they finally relented and said to watch the sea surface temperature for the signal. Well, sure enough, as they sailed up to the Gulf Stream, there was a line of clouds along the boundary between the cooler greenish continental shelf water and the deep blue Gulf Stream, the weather was different, with wind and waves changing, and fish were jumping and birds diving along the oceanographic front of the West Wall of the Gulf Stream. The Gulf Stream literally smelled different. They then experienced the Gulf Stream for several days, as they hove to under bare poles during a storm, but still were carried along at four knots. In reading the student journals at the end of the six week voyage, it was clear that they were all going to remember the Gulf Stream for the rest of their lives.

Immersive education is an active learning experience. It is more powerful than simply "teaching," and connotes an active, rather than a passive experience. The objective is learning through experience and the subject content that the student absorbs is through these experiences with nature and their surroundings, rather than via lectures. When a student picks up a book or reads primary scientific literature, it is in the context of understanding an observation or interpreting their results, rather than content that is delivered by an instructor for later testing.

Immersive education is participatory and collaborative. Group work is central to the process. Students form small groups or "student research teams" (generally 4-6 students per team) that work together to study an aspect of nature. The teams are given enough time together to formulate hypotheses, design observations or experiments to test their hypotheses, and divide up the tasks between themselves. While the instructors circulate among the groups to ensure they are coming up with doable and interesting questions, the students are encouraged to self-organize and develop allocations of tasks that are equitable and utilize the different skill sets that individual team members possess.

Advantages of Immersive Education

There are several advantages of immersive education over traditional classroom teaching for teachers.

1. Teachers are generally "learning junkies," and immersive education provides them with new data and new ideas which can stimulate further research.
2. The immersive setting provides teachers with insights into the personalities and capabilities of students. It is easier to assess a student project when the student is in front of you and there is more than a faceless name on a piece of paper. Advising or selecting students for future academic or professional development becomes easier as well.
3. Teachers get good feedback on the student's mastery of a subject, and can better appreciate what aspects of their teaching need to be modified. More than correct answers on an exam, the teacher can determine whether the students can apply their learning.
4. The enthusiasm of students being exposed to nature can serve to reinvigorate teachers. Being able to see something through the eyes of students who are seeing or doing something for the first time can inspire a teacher to better teaching.

After teaching in immersive settings for thirty years, we would like to reflect on the life lessons to both teacher and student that transcend the course content or subject matter.

1. The amazing amount of research and learning that can be accomplished by a small team of focused people in a short amount of time is an important illustration of what is possible, given the right conditions. This can promote students and teachers to enable these right conditions for productive collaborations in other endeavors. As Margaret Mead said, "A small group of thoughtful people could change the world. Indeed, it is the only thing that ever has." (Anon (b) 2012).
2. Immersive education provides both student and teacher with memorable events and meaningful experiences. Observing bioluminescence, stars, or sea creatures can be memorable, and pushing one's boundaries

physically, mentally, or emotionally by working closely together can be meaningful.

3. Developing personal relationships in an immersive learning setting can lead to life-long relationships. Meeting and getting to know interesting people is facilitated by the immersive nature of the setting. Bill's ground rules on personal relationships for students and instructors during a course are no "special relationships" that serve to disrupt the group dynamic.
4. Both as students and instructors, we have been inspired by experiences in immersive education settings. We feel as though we learned more, and learned more deeply. The enthusiasm generated by group dynamics has fueled our passion for environmental science and for the preservation of ecosystem health so that future generations can experience nature.

There are some biological realities that traditional classroom settings attempt to ignore. One reality is that the attention span of an average adult, particularly young adults, is twenty minutes or less. This means that the typical one hour long class is well over the limit. Simply sitting still for extended periods causes the brain to function at reduced capacity as well. Young adults have a lot of energy and forced inactivity does not promote constructive thinking. Another reality is that different people learn better in different ways, often divided into visual, auditory, and tactile learning modes. The traditional classroom is largely auditory, with varying amounts of visual and little if any tactile learning. An immersive education experience can promote a variety of learning opportunities. Many academics believe that students typically learn more from their classmates than they do from their instructors. This means that the teacher-centric classroom setting where students are admonished to "keep quiet" is working at odds with the learning style of students. Given these realities, why do we persist in delivering most of our teaching through traditional classrooms?

Overcoming Impediments to Immersive Education

There are several impediments to implementing immersive education over traditional classroom teaching in university settings.

1. Financial. The financial efficiency of a single instructor delivering a lecture course to tens or even hundreds of students is contrasted with the need for a teacher and teaching assistants to deliver a course to only two dozen students who need to be housed and fed in remote settings. While this is false economy, the costs of running a field course are often an impediment to students (travel costs and additional fees) and institutions (remuneration based on credits and student numbers).
2. Burn-out. The immersive setting means that teachers are interacting with students intensely. This is challenging emotionally. Leading field trips and trying to keep up with students that are decades younger can be exhausting. Upon returning to campus after an exhausting field course, colleagues typically treat the teacher's time away as vacation.
3. Inertia. The challenge of doing something that is off-campus, uses different testing and assessments, and is difficult to assign credit hours takes extra energy on the part of the teacher and the various university administrators. It is always easier to resort to the tried and true lecture setting.
4. Safety. The opportunity for accidents to occur in remote settings without easy access to medical facilities can be a deterrent for both students (particularly parents of students) and university administrators.

While financial, burn out, inertia, and safety issues do pose very real deterrents to delivering immersive education experiences, various mechanisms have been developed to overcome these concerns. Creative funding models that tap additional resources to underwrite student costs, and/or provide remuneration via a lecture-based course component are examples used to

overcome financial barriers. Developing a time-in-lieu policy which allows instructors to recover from field trips can reduce burn-out. Reward systems for teachers and support personnel can encourage them to overcome inertia to create and maintain immersive education programs. A fairly strict code of practice needs to be developed for students, as well as provision of first aid supplies and training for teachers.

Two examples of immersive education follow. They illustrate the teaching effectiveness of this approach and the difficulties in sustaining these programs.

Examples of Immersive Education

Example 1

Sea Semester. This program is operated by a private, non-profit organization, Sea Education Association, based in Woods Hole, Massachusetts. The basic course format is to teach students both nautical science and marine science in a classroom setting for six weeks in a shore component. This is immediately followed by a six week sea component where the students join a tall ship and serve as deck hands and scientists. By the end of the six week sea component, the students are expected to run the ship and the science program, providing a powerful motivator for learning. This program has been running for forty years, has an impressive set of alumni, logged over a million nautical miles with an impressive safety record, yet struggles every year financially. The costs of running seagoing vessels are considerable and prone to inflationary pressures, and the students have an increasing diversity of less expensive (and less challenging) options for a semester abroad or a shorter version (e.g., two week sail vs. a full semester). Class size is limited by ship berths, so approximately twenty-five students per ship can be accommodated. Each student conducts a project aboard the tall ship and presents their findings to the class at the conclusion of the course. Some of the data collected by students are published in scientific journals.

Example 2

Field course in coral reef biology and geology. This course was team-taught at The University of Queensland for over twenty years by academic instructors from zoology, botany, and geology. A full semester course was delivered on the main campus which had enrollments in excess of one hundred students. The top twenty five students from the on-campus course were offered the opportunity for the two week course at the Heron Island Research Station on the southern Great Barrier Reef. The field component included reef walks, snorkeling and diving trips, topical lectures, and projects with written and oral presentations at the end of each week. The number of students who went on to professional careers in marine science was considerable. The course was discontinued when key faculty retired or left the university.

Some Outcomes of Immersive Education

Three important personal traits can be fostered in immersive, experiential learning; knowledge, passion, and persuasive capacity. Knowledge, particularly deep knowledge about an ecosystem, is obtained from extended direct exposure to the ecosystem, supplemented with a strong intellectual framework obtained through academic teaching and research findings. Passion for an ecosystem is also generated from extended direct exposure. In addition, the increased understanding of ecosystem features and threats often creates a conservation ethic that leads to passion. The persuasive capacity to convince other people of the need for appropriate actions to preserve or restore ecosystems is generated from the knowledge and passion, analytical and communication skills gained in experiential learning, and can lead to social change.

There are several key components to immersive education that enhance both individual and group learning. An important component is the written and oral communication of research findings at the end of the research projects. The act of synthesizing and communicating the findings provides an opportunity for insights and improved understanding. Sharing research findings between the different research teams also provides a synergistic opportunity for comparisons and contrasts that can create broader synthesis than

could be generated with individual projects. Students also obtain a sense of satisfaction for the completion of their project and can appreciate their accomplishments by finishing in a timely manner. Another component that can result in group learning is a constructive, facilitated critique after the presentations in which the clarity of the science and the communication of the science are discussed by the entire class. In this way, students learn by both direct and indirect critiques, as well as learn how to ask good questions, and how to analyze and interpret scientific results. It is often the first opportunity they may have to develop the skeptical rigor necessary for the proper analysis of scientific results, as well as receive constructive feedback on their work from classmates. Finally, most students need to be dissuaded that they have not collected enough data or done enough analysis for their work to be considered a "real" scientific study. In fact, peer review publications can be generated from student project results, and the data generated in student projects can stimulate further research proposals and projects.

Defining Immersive Education

The above examples show that immersive education places students directly in the water environment that is home to their interests and uses the experiences they gain as a way to learn about, reflect on, and advocate for, the better understanding and management of this water environment (Lucas 1979). Immersive education echoes the exhortations of Agassiz, refocusing both the student and the teacher on the object of study and the context in which it occurs. The examples presented here highlight many aspects of immersive education. In summary, immersive education:

- Is experiential and real. Students are face-to-face with the object of their study. They are physically and mentally surrounded by and enmeshed in the environment that supports this object.
- Is process-driven. It involves formulating and testing hypotheses, linking and testing relevant content, processes, and personal and social values.
- Is trans-disciplinary. Students view the object of study through many disciplinary windows and seek links between knowledge gained and ways to value that knowledge.
- Encourages critical thinking. Observations are not accepted at face value. All data collected and analyzed are subject to close scrutiny, as are any conclusions derived from this analysis.
- Renegotiates power in relationships between participants. In traditional classroom situations teachers control the pedagogic process. In immersive education students are empowered to guide the learning process.
- Is participatory and active. Where possible, data are gathered directly and students are purposefully involved in gathering, analysis, and synthesis of findings.
- Is collaborative. Students work in groups. All aspects of the immersive process involve students working with and reflecting on their findings with both their peers and teachers.
- Provides personal experiences that are memorable and potentially life-changing. Students may become advocates for a particular viewpoint, based on these experiences.
- Develops passion and persuasive capacity. Advocacy skills may be developed as a part of the process.

In Conclusion

While the above list of characteristics may appear somewhat idealistic, it may be a useful checklist for teachers designing immersive education programs. Many of the characteristics found in the two examples and the discussion in this paper (e.g., process driven; trans-disciplinary; requiring critical thinking and renegotiation of power found in relationships between participants; participatory; collaborative) are also, or ideally should be, characteristic of emerging, complex fields of knowledge such as integrated water management.

Our anecdotal observations of the high rates of career success in graduates of immersive education lead to the supposition that there are lasting positive

impacts of learning in this style that transcend the actual course and benefit the students (and instructors) later in their careers. A case could be made for developing some good longitudinal studies in which the career trajectories of students with and without immersive education are compared over many years. The pre-selection of students drawn to this teaching mode is also relevant, as the most enthusiastic and keen students will vie for these opportunities. Another aspect that is not typically valued, but can be quite important to individuals, is the personal realization that students may gain from the intense exposure that a certain subject or career path is, in fact, not what they wanted after all. Young people often need to learn what they do *not* want to do so that they can better decide what they do want.

There are many powerful reasons for developing immersive education to either augment or replace traditional classroom teaching. There are advantages of this mode of delivery for both students and instructors. In addition to giving students a deep knowledge of the subject matter, there are some good life lessons to be gained. Teaching in a non-traditional mode does present some challenges, but innovative approaches and persistence can overcome the impediments. Examples of immersive education demonstrate both the tremendous capacity that these programs can unleash, but also the fragility of maintaining these programs. The long-lasting impacts of this type of learning can be appreciable, and research as to such impacts is needed. Our conclusion as immersive educators is that Louis Aggasiz's succinct, hand-painted sign, "Study nature, not books," still resonates today.

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References

Addante, R. 2009. Woods Hole Marine Biological Laboratories. *Rick Addante's Gallery*. Available at: https://picasaweb.google.com/113005675764974117693/WoodsHoleMarineBiologicalLaboratories.

Anonymous (a) 1879. In the Laboratory with Agassiz. *American Poems*. 3rd Edition, Houghton, Osgood and Company, Boston, 450-454.

Anonymous (b) 2012. Quotations by Author: Margaret Mead (1901-1978) United States Anthropologist and Popularizer of Anthropology. Available at: http://www.quotationspage.com/quotes/Margaret_Mead/.

Ashford, N.A. 2004. Major challenges in engineering education for sustainable development - What has to change to make it creative, effective, and acceptable to established disciplines? *International Journal of Sustainability in Higher Education* 5(3): 239-250.

Biswas, A.K. 2004. Integrated Water Resources Management: A Reassessment. *Water International* 29(2): 248-256.

Cummins, J. 1998. Immersion education for the millennium: what have we learnt from thirty years of research on second language immersion? In Childs, M.R. and R.M. Boutwick (Eds.) *Learning Through Two Languages: Research and Practice*. Second Katoh Gakuen International Symposium on Immersion and Bilingual Education, Katoh Gakuen, Japan, 34-47.

Ferreyra, C. and P. Beard. 2007. Participatory evaluation of collaborative and integrated water management: insights from the field. *Journal of Environmental Planning and Management* 50(2): 271-296.

Freire, P. 1993. *Pedagogy of the Oppressed*. 2nd edition, Continuum Publishing Group, New York.

Gilbert, J.H.V. 2005. Interprofessional learning and higher education: Structural barriers. *Journal of Interprofessional Care* 19(1): 87-106.

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Participatory Learning and Popular Education Strategies for Water Education

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Abstract: This paper presents some experiences of bringing critical pedagogy and participatory learning approaches into postgraduate university classrooms in teaching about water and sustainable development. Employing critical pedagogy and participatory approaches offer ways of escaping conventional lecture and tutorial approaches to pedagogy in university, strategies for incorporating and sharing student knowledge and experience, engaging students in the production of theory and knowledge (and not just their consumption), and problem-posing approaches that encourage critical thinking and creativity. First I discuss the need to break away from conventional university teaching approaches and the usefulness of critical pedagogy and participatory perspectives that seek education for social change. Then I explore four elements of participatory learning that have been effective in my water education practice and seem to offer lessons for innovation in water education in higher education. These elements are i) asset-based teaching and learning, ii) participatory learning to enable deliberative processes and collective learning, iii) problem-posing pedagogy, and iv) involving students in construction of knowledge.

Keywords: *Water, education, participatory learning, critical pedagogy*

An appeal to participation and participatory pedagogies has become something of an orthodoxy within environmental education and education for sustainable development (Reid et al. 2008; Tilbury 2012; UNESCO 2012). There seem to be several reasons for this and it is worth highlighting some of them here as a way to justify participatory learning approaches in water education.

First, formal education in institutions such as schools and universities has been subject to a sustained analysis and critique by critical pedagogy (and other fields) (Darder et al. 2003; Freire 1972; Shor 1987). Critical pedagogy is both a radical critique of conventional education and an approach aiming to democratize educational processes and empower students for progressive social change (Darder, Baltadano, and Torres 2009). It has been deeply influenced by Frierian critiques of formal education and his ideas of dialogue and problem posing education. According to Nina Wallerstein (1987: 33):

> Freire's central premise is that education is not neutral: whether it occurs in a classroom or in a community setting, the interaction of teacher and student does not take place in a vacuum. People bring with them their cultural expectations, their experiences of social discrimination and life pressures… Education starts from the experiences of people, and either reinforces or challenges the existing social forces that keep them passive.

As Giroux (2009: 452) writes, critical pedagogy sees universities and "schools as social and political sites involved in the struggle for democracy." Therefore, critical pedagogy also concerns itself with radically transforming formal education and educational institutions, and argues that education for social change requires an explicit awareness of the power relations and inequalities built into schools and universities.

Paulo Freire's ideas and writings on education for social change have also influenced popular education. Popular education here refers to education that seeks to support organizing or activism for social justice, democracy, and environmental goals (Crowther et al. 2005). It is a

form of radical adult education and hence usually takes place in non-formal education contexts and often draws on Frierian approaches to dialogic education (Kane 2001). Popular educators regard the community as the key source of knowledge and the starting point for learning (Arnold 1991). Popular education sees empowerment and "transformation" as necessarily a collective process and explicitly encourages learning processes that lead to collective action for social change.

Popular education methods and strategies are widely practiced in non-formal education and non governmental organization programs throughout both the developing and developed world. There has been constant interaction and cross-fertilization between participatory development and popular education as both are concerned with social justice, community education, collective action, and social change. To a certain extent, they come together in approaches to adult education and training in international development contexts, such as the dialogic approaches of Hope and Timmel (1995), Vella (1989; 2002) and Participatory Learning and Action (see Pretty et al. 1995, and the Journal Participatory Learning and Action). Environmental education and education for sustainable development practitioners often draw upon such educational traditions, especially in adult education, nonformal and non governmental organization contexts.

Despite a long standing – but marginalized – interest in education for social change in many universities (Shor 1987), the higher education sector has proved particularly resistant to the ideas and innovations of critical pedagogy and popular education (Crowther et al. 2005). Recently, however, there has been some resurgence of interest in participatory and dialogic approaches to learning participatory development in university contexts (e.g., Taylor and Fransman 2003; 2004).

Critical pedagogy and popular education challenge us as educators to think critically and reflexively about not only the content of education but also the process and practice of teaching and learning. These traditions seek to avoid the authoritarian and teacher-centred processes of much formal education, and to empower students by enabling collaboration and negotiation between students and teacher to determine learning goals and processes. Participatory learning also provides "tools for developing and sharing knowledge, skills, and experiences that ideally lead to cognitive gains, action competence, and community building" (Reid et al. 2008: 2).

For the rest of the paper I will explore some of the ways I have attempted to put these ideas and learning strategies into practice in teaching about water and sustainability in university classrooms. How can we engage students and enable them to see themselves as agents of social change and not just consumers of pre-packaged knowledge?

Asset-Based Learning and Teaching

Critical pedagogy advocates avoiding "banking education" (Friere 1972), teaching that "deposits" into students the knowledge and skills authorized by the teacher. Conventional teacher-centred education employs a "deficit approach" to students in the classroom – positioning the teacher as the subject expert and the students as lacking the knowledge, skills, and attitudes that the subject curriculum will convey. Deficit approaches effectively silence students, frame them in terms of a one-dimensional "student" identity that overlooks the wealth of individual experience, knowledge, interests, and attitudes that students bring to education.

Asset-based learning seeks to employ the insights and approaches of asset-based community development (ABCD) to teaching and learning in the university classroom. A fundamental insight of ABCD was that much conventional community development (and indeed international development) took deficit approaches to the target populations and communities they sought to help. That is, they perceived and labelled target groups in terms of deficits or lacks – poverty, unemployment, lack of education and skills. This is a very disempowering discourse, enlisting "poor" or "disadvantaged" groups as clients into a welfare system that maintained them in a dependent position (McKnight and Kretzmann 2005). The deficit perspective effectively silences target communities and blinds development workers to seeing the strengths, knowledge, skills, and other kinds of human, cultural, social or material resources possessed by communities. In other words, the assumptions

informing deficit approaches help to create and maintain a relationship of power and disadvantage between development worker and client group.

To deficit assumptions and their consequences, ABCD holds that the development worker is not an "expert" bringing the benefit of her knowledge and authority to the community, but rather should see local community members as the "experts" on their own local conditions, resources, knowledge, culture, values, priorities for change etc. From this perspective the development worker establishes a relationship based on dialogue, partnership, and facilitation (Kretzmann and McKnight 1993).

Asset-based teaching and learning therefore seeks to apply strategiessimilar to those of ABCD but in the classroom, and in doing so avoid a deficit approach and its consequences. Instead, it makes student experience, knowledge, and attitudes into fundamental and valued resources for learning and relationship building. The teacher steps down from the role of expert and acts as a co-learner and facilitator, engaging the learners in dialogue starting from their knowledge and expertise. This is one of the most powerful reasons I have found for abandoning conventional "stand and deliver" lectures. Lectures (and most conventional tutorials) devalue and silence the knowledge, experience, and expertise that students bring and marginalize opportunities to draw upon student expertise.

A starting point for asset-based learning in the classroom is to conduct an inventory of student "assets," and use the inventory to forefront and highlight the knowledge, experience, and social capital students bring as learning resources. There are many ways to do this of course. When I first started trying to incorporate ABCD into teaching and learning I drew directly on a workbook, Discovering Community Power, developed for community development by the ABCD Institute (Kretzmann et al. 2005). I usually do this activity very early in the course as it provides an engaging way to introduce students to asset-based approaches to sustainable development, at the same time as getting to know each others' "assets." Students work in small groups to conduct an inventory of their individual experience, skills, and talents; their social networks, clubs, and organizations; and the institutions (such as universities, hospitals, media, etc.) to which they have a connection, as well as other local assets that they might be able to mobilize for a particular community development purpose. The outcomes of the activity are always surprising and enlightening about the depth and diversity of what students can contribute.

More recently, I have adapted a framework commonly used in education and teaching – "Head, Hands, and Heart" (Peter Oliver, personal communication). This is an activity that facilitates students recording and sharing their knowledge and qualifications (matters of the head), their experience (matters of the hands), and their deeply held interests, hobbies and "passions," and their hopes and dreams for their future (matters of the heart) – and gets them to think about how those different assets could contribute to class knowledge and learning goals on the topic at hand.

The value of such an asset-based approach is borne out every year in teaching masters by coursework students a class in water and sustainable development. Importantly, not only does such an activity highlight the importance of students learning from each other, but it helps to contextualize the lecturer as a person with useful knowledge and experience rather than THE topic expert in the classroom. For example, in 2012 in a class of 28 students, the students originated from 16 different countries, came with 10 different disciplinary backgrounds (from human geography, political science to environmental engineering, hydrology). The great majority (24 out of 28) had at least two years professional experience in their fields, and most of those had worked in water-related sectors. The great majority had either volunteer or paid professional experience in developing countries. In the very first class together it became very clear that their combined years of work experience related to water resources development far outweighed the experience of the lecturer in the room (me!) and most realized that there was possibly more to learn from each other than from the academic "expert."

Dialogue and Problem-Posing Learning

Dialogue involves mutual respect between educators and learners. It requires educators to step down from the conventional position of power and

authority that educational institutions place them in and positioning them as co-learners working with learners and participants. Everyone in a group has some knowledge they can contribute and gaps in other areas and everyone seeks to learn collectively. A dialogic approach aims to position students as active subjects acquiring and constructing their own critical knowledge, rather than as passive recipients of knowledge determined by powerful institutions.

Such a dialogue is most meaningful when it starts from the lived experience, needs, and aspirations of participants. Therefore, popular education respects community members' culture, ways of life and aspirations. Dialogue is a cooperative process of analyzing and learning about the world. It aims to help learners develop a deeper critical understanding of their place in society, especially the sources of inequality that constrain their own lives. Therefore, in dialogue the educator poses problems that stem from key social forces shaping participants' lives – the social, economic, and cultural contexts that impact on individual lives. Freire (1972) calls these key problems "generative themes." The aim is for participants to take charge of their own learning, to raise generative themes and pose problems to the group themselves. Popular education aims to enable learners to acquire critical knowledge and take action in order to make a difference in the world.

Problem-posing in popular education generally aims to challenge community members to analyze and engage with the social forces constraining their lives (Arnold et al. 1991; Freire 1972). In my own practice in the university classroom, I have tended to interpret the dialogic approach more in terms of Freire's proposal that the educator step down from the role of expert and approach learners as equals, posing problems and questions to engage them as participants in the process of investigating, analyzing and producing knowledge. This is more in line with approaches to participatory and dialogic learning advocated by Shor (1987), Vella (2002), Pretty and his colleagues (1995) and even influential health educators such as Werner and Bower (1982).

So, what does this mean in water education? Taking a dialogic, problem-posing approach can mean engaging students in sharing knowledge and analyzing problems throughout an entire course and not just in an independent capstone project at the end. For example, on the first day of a course on water and sustainable development, students draw rough maps of river basins they are familiar with, often choosing basins where they grew up and have direct personal experience. They present the maps to each other and explain economic, social, and environmental issues in their river basin, and begin the process of analyzing what "sustainability" means or could mean in their chosen context. In one exciting session, students from different disciplinary backgrounds used these maps to explain how their particular academic discipline (e.g., engineering, chemistry, fresh water ecology, management) would "read" and understand the river basin. This led to a stimulating discussion and debate about how such different disciplines could talk to each other and be integrated.

Participatory Learning – Collective and Deliberative Process

It is not only important to validate the great diversity and depth of individual and collective experience that students bring to the class, but to find ways to share knowledge and useful learnings with each other. I have found that facilitating participatory workshops is an effective way to draw upon student expertise as a resource but also to challenge students to analyze and apply their existing knowledge and expertise in new ways and thus extend it. One very effective approach is the popular education strategy of using analysis to look for patterns in students' or participants' own lived experience (Arnold et al. 1991).

Participatory learning encompasses a range of techniques and methods for facilitating and enabling students to come together in groups (usually small groups) to share knowledge and ideas, discuss, debate and deliberate, analyze and critique, and construct and create knowledge and theory (Pretty et al. 1995). Participatory learning aims to enable a kind of deliberative democracy in the classroom – a collective and interactive process.

Participatory learning is underpinned by group facilitation techniques widely known and used in adult and popular education, community

development and participatory training. For example, Participatory Learning and Action, widely used in rural and community development, provides an extensive toolkit of interactive mapping, modeling, ranking, diagramming, and matrix techniques for working with groups of people to enable them to collectively compile, systematize, and analyze local knowledge and information (in other words, conduct research), with a goal of using and applying that knowledge in collective planning and implementation of local development activities.

Participatory Learning and Action also provides educators with a "toolkit" of facilitation techniques that can be applied in and adapted to a wide range of contexts, as well as education and training situations. Some people use the term Participatory Learning and Action, arguing that the approach has much broader application than just "appraisal" in "rural" contexts (see the online journal Participatory Learning and Action). Such Participatory Learning approaches, however, are much more than sets of useful facilitation methods. Underpinning them is a set of attitudes, values, and ideology that respects student knowledge, experience, and aspirations, values dialogue and participatory democracy, and seeks social change and social justice (e.g., Chambers 1997; 2002; Pretty et al. 1995).

Construction of Knowledge

Popular education and critical pedagogy seek to turn students from passive consumers of knowledge determined and transmitted by the expert lecturer, into active constructors of knowledge in the learning process. This, of course, is part of the dialogic and problem-posing process.

Paulo Friere (1972) argued that uncritically consuming knowledge transmitted by powerful institutions like schools and universities is inherently disempowering. Students are effectively silenced. The role of the critical educator, according to Friere, is to challenge students and enable them "to become aware of the world around them as something they can change" (Newman 1999: 41). This means helping them find their own words and language for understanding and analyzing their world. It means starting from their own experience and acquired knowledge, developing critical thinking skills to evaluate and draw on different kinds of information and concepts, and developing and articulating knowledge, analysis and action that can be applied to changing their world.

As Taylor and Fransman (2003: 8) write about development education, "A basic concept of learning and teaching participation is that individuals participate in generating their own personal theories which are relevant to their own context." I have found that working with students to challenge them to analyze and develop their own theory is a very effective form of participatory learning, building upon and analyzing previous experience and knowledge and engaging them in the production of knowledge, not just its consumption.

In the water and sustainable development class, students construct knowledge in a broad range of ways, both individually and in small groups. In participatory learning sessions they develop principles for effective community participation based on their own experiences and reading of case studies and water development literature, they formulate methods for conflict management, and strategies for effective networking in the water sector. At the International Water Centre we have tried to integrate this philosophy of knowledge production into assessment processes as much as possible. In the water and sustainable development class, students in small groups research, design and deliver their own participatory learning workshops to engage their fellow students in learning about new methods for participation in water resources development. In Problem-Based Learning assignments they draw upon a range of disciplinary knowledge to analyze particular problems in particular contexts, and design their own development projects to achieve integrated water resources management and sustainable development.

Conclusion: Students Learning to be Critical Thinkers and Agents of Change

If universities are going to educate professionals to have the knowledge, skills, and attitudes needed to work towards integrated water resources management and sustainability in the water sector, then I believe they need to be critical thinkers with the confidence to challenge all kinds of institutional

knowledge and conventional ways of thinking. They need to see themselves as agents of change and not just professionals looking to slot into an existing "career" and industry. They need an appreciation of participatory development and all that it implies in terms of valuing and involving a range of previously marginalized groups in water decisions. Educating people with those sorts of critical thinking skills, sense of agency and participatory outlook requires us to think about pedagogy as process and not just content. I have argued here that critical pedagogy, popular education, and participatory learning offer pedagogical strategies and processes that can inform our water education in useful ways to achieve such ambitious educational goals. Indeed, these educational traditions have all been influential in current approaches to Education for Sustainable Development, especially as it is practiced in nonformal and community contexts.

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References

Arnold, R., B. Burke, C. James, D. Martin, and B. Thomas. 1991. *Educating for a Change*. Ontario: Between the Lines & Doris Marshall Institute.

Chambers, R. 1997. *Whose Reality Counts? Putting the First Last*. London: Intermediate technology Publications.

Chambers, R. 2002. *Participatory Workshops: A sourcebook of 21 sets of ideas and activities*. London: Earthscan.

Crowther, J., V. Galloway, and I. Martin (Eds.) 2005. *Popular Education: Engaging the Academy*. Leicester: NIACA.

Darder, A., M. Baltodano, and R.D. Torres (Eds.) 2003. *Critical Pedagogy Reader*. New York: RoutledgeFalmer.

Freire, P. 1972. *Pedagogy of the Oppressed*. London: Penguin.

Giroux, H.A. 2009. Teacher Education and Democratic Schooling. In Darder, A., M. Baltodano, and R.D. Torres (Eds.) *The Critical Pedagogy Reader*. New York / London, Routledge Falmer, 438-459.

Hope, A. and S. Timmel. 1995. *Training for Transformation: A Handbook for Community Workers*. Revised edition, Gweru, Zimbabwe: Mambo Press.

Kane, L. 2001. *Popular Education and Social Change in Latin America*. London, Latin America Bureau.

Kretzmann, J. and J. McKnight. 1993. *Building Communities from the Inside Out: A path towards finding and mobilizing a community's assets,* Asset-Based Community Development Institute, Evanston, IL.

Kretzmann, J.P., J.L. McKnight, S. Dobrowski, and D. Puntenney. 2005. *Discovering Community Power: A Guide to Mobilizing Local Assets and Your Organizations Capacity*, available from Asset-Based Community Development Institute.

McKnight, J. and J. Kretzmann. 2005. Mapping Community Capacity. In Minkler, M. (Ed.) *Community Organizing and Community Building for Health*. Rutgers University Press, New Brunswick.

Newman, M. 1999. *Maeler's Regards: Images of adult learning*. Sydney, Stewart Victor Publishing.

Pretty, J.N., I. Guijt, J. Thompson, and I. Scoones. 1995. *Trainer's Guide for Participatory Learning and Action*. London: International Institute for Environment and Development.

Reid, A., B.B. Jensen, J. Nikel, and V. Simovska. 2008. Participation and learning: developing perspectives on education and the environment, health and sustainability. In Reid, A., B.B. Jensen, and V. Simovska (Eds.) *Participation and Learning: Perspectives on Education and the Environment, Health and Sustainability.* Springer, 1-18.

Shor, I. (Ed.) 1987. *Freire for the Classroom*. Heinemann.

Taylor, P. and J. Fransman. 2003. Learning and teaching participation in institutions of higher learning: overview. *PLA Notes* 48.

Taylor, P. and J. Fransman. 2004. Learning and teaching participation: Exploring the role of higher learning Institutions as agents of development and social change. *IDS Working Paper* 219.

Tilbury, D. 2012. Higher education for sustainability: A global overview of commitment and progress. In *Higher Education in the World 4 Higher Education's Commitment to Sustainability: from Understanding to Action*. Basingstoke, Palgrave Macmillan / GUNI, 18-27.

UNESCO. 2012. *Education for Sustainable Development Sourcebook*, Paris, UNESCO.

Vella, J. 1989. *Learning to Teach: Training of Trainers for Community Development*. Washington: Save the Children & OEF.

Vella, J. 2002. *Learning to Listen, Learning to Teach: The Power of Dialogue in Educating Adults*. Revised Edition. San Francisco: Jossey-Bass.

Wallerstein, N. 1987. Problem-posing education: Freire's method of transformation. In Shor, I. (Ed.) *Freire for the Classroom*. Heinemann.

Werner, D. and B. Bower. 1982. *Helping Health Workers Learn: A book of methods, aids, and ideas for instructors at the village level.* Hesperian Foundation, Palo Alto.

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Cross-Boundary Peer Learning in the Mekong: A Case of Field-Based Education in Natural Resources Management

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Abstract: This article analyzes the process and output of a cross-boundary peer learning exercise about policy and implementation on natural resource management in the Mekong. The exercise involved university students and academics from Cambodia, China, Thailand, and Australia. The pedagogic approach taken was student-centred learning, whereby students learned with and from their fellow students, and about their peers' perspectives in other Mekong countries on similar issues. The article consists of four parts. The first part introduces the exercise and discusses conceptual frameworks including cross-cultural learning, peer-based learning, and experiential learning. The second part describes the Mekong Learning Initiative research exchange program, explaining the process by which students from different countries and different learning cultures engage in peer-based learning. The third part uses students' own reflections to show ways in which learning outcomes from the student research exchange differ from conventional learning activities. The discussion section draws on the successes and challenges of the exercise to explain how we as teachers engage with adaptive learning for both research and pedagogic purposes, to identify elements critical to enhancing experiential learning in the cross-boundary peer based learning situation.

Keywords: *Cross-boundary, peer learning, experiential learning, natural resource management, Mekong*

The Mekong has been the subject of a great deal of research and institutional innovation, both in the fields of regional economic integration (Australian Mekong Resource Centre 2007; Oehlers 2006) and of transboundary river basin management (Hirsch and Jensen 2006; Lebel et al. 2007). The Mekong Region as a cooperative development arena and the Mekong River Basin as a shared resource are represented institutionally through the Greater Mekong Subregion framework and the Mekong River Commission respectively. Bilateral and other multilateral institutions have also proliferated to respond to emerging challenges and opportunities. Increasingly, and despite considerable obstacles, such intergovernmental arrangements have been mirrored by non-governmental initiatives and strategies to develop civil society linkages through a kind of "regionalization from below" (Hirsch 2001; Khaosa-ard and Dore 2003).

To date, however, active educational linkages within the Mekong framework have been quite limited. Within each riparian country, teaching about development, environment, and natural resource management has been limited mainly to generic knowledge, case studies from within each country, or textbook-based examples from other parts of the world. Despite high-level initiatives among university administrators such as the Greater Mekong Subregion Academic Research Network, there has been sparse exposure of teachers and students to comparative material from neighboring countries, and limited understanding among tertiary-level students of the Mekong River Basin as a shared resource or the Greater Mekong Region as an integrated development arena. This means that university students as the new generation of professionals continue to lag behind the rapid pace of regionalization in terms of a shared knowledge base and mutual

understandings of diverse perspectives in different countries of the region.

In this paper, we present an innovative exercise designed to be a modest building block in the construction of a regional learning community. The exercise is a research-based teaching exchange (hereafter referred to as "research exchange") between programs at Yunnan University in China, Ubon Ratchathani University in northeast Thailand and the Royal University of Phnom Penh in Cambodia. The Yunnan students are enrolled in a Master of Human Geography, which emphasizes development issues with a primary focus on China and draws case studies mainly from Yunnan. The Ubon Ratchathani students are taught by the Department of Social Sciences, Faculty of Liberal Arts which offers both undergraduate and graduate degrees in Social Development. The main focuses of the program are social sciences research methodology and development theory, providing students with basic skills through a practicum course outside the classroom. The program includes field-based learning in communities, and most of the field work is in northeastern Thailand. Therefore, learning about neighboring countries is very limited. The Royal University of Phnom Penh students are undertaking an undergraduate degree in Environmental Science. The program mainly focuses on classroom-based teaching within inter-disciplinary fields relevant to natural resources and environmental management. Field-based learning has the status of a supplementary course without credits. In all three cases, therefore, there is limited opportunity for learning outside the classroom and beyond the national context.

The cross-boundary research exchange is innovative in two main respects. First, it is a central activity of the Mekong Learning Initiative, the first significant attempt to develop a practical collaboration between teachers and students in cognate areas of environment, natural resource management, and rural social change at eight universities in five Mekong counties. Second, it challenges conventional teacher-focused classroom-based learning through development of a field-oriented approach that we refer to as cross-boundary peer learning. The research exchange concept emerged from a series of eight workshops held under the auspices of the Mekong Learning Initiative between 2003 and 2008 to develop teaching materials and teaching methods within an experiential learning framework.

Cross-boundary peer learning draws from, but does not limit itself to, three main educational concepts. The first is cross-cultural learning, which means understanding ways in which particular phenomena and issues are perceived and interpreted in other cultures and across academic disciplines. It encourages students to view issues from other cultural perspectives. It goes beyond just awareness and appreciation of other cultures, allowing a student's views to broaden and transform as a result of cross-cultural experiences (Myers et al. 2005). Further, the complexity of humanistic and social phenomena calls for a trans-disciplinary approach to study. Transdisciplinarity is not simply a case of combining disciplines, but instead deals with issues by forming new frameworks from constituent disciplines (Russell 2005). A single issue can thus be understood across both national and disciplinary cultures. In our case, the key issues involved concern the relationship between policy on decentralized natural resource management and the experience of its implementation at the village level. The issues are perceived and interpreted in three different country contexts and through diverse academic disciplines, ranging from rural sociology through geography to environmental science.

The second main concept is peer learning. This takes the focus of learning off the teacher as a repository of knowledge and facilitates mutual learning between students of similar ages, levels of educational attainment and subject interests. The research exchange was designed around the premise that peers have the potential to establish a unique learning situation, distinct from the teacher-student interaction, in which they have close connections, active involvement with one another and ease of communication (Goldschmid and Goldschmid 1976). Although peer learning is an effective way to learn (Boud et al. 1999), without adequate organization and structure it can easily fail (Goldschmid and Goldschmid 1976). A recent study systematically analyses forms of peer tutoring and cooperative learning and identifies critical elements to make peer

learning more effective (Topping 2005). In our case, peer cooperative learning is an integral part of the cross-boundary learning process, as students from Cambodia, China, and Thailand develop knowledge and perspectives on each other's countries through their peers first, policy makers and villagers second, and only then through their and their peers' teachers. Similarly important to the learning process is the different academic background of participating students as well as their teachers.

The third and related educational approach underlying the cross-boundary peer learning employed in the research exchange is experiential learning (Kolb 1984). Experiential learning emphasizes that knowledge results from the combination of undergoing and transforming experiences. To learn from experience requires preparation for the experience, engagement in educational activities and evaluation (Wilson 1982). For present purposes two key components of the approach are salient. First is the direct experience of issues, for example through fieldwork. Second is the learning cycle, whereby understanding is produced iteratively through experience, facilitated reflection, and assisted conceptualization. The cycle is repeated in new empirical contexts.

We commence our account of a cross-boundary peer learning exercise in the Mekong by contextualzing the research exchange within the Mekong Learning Initiative program and describing the basic logistics and design of the exercise. The learning outcomes are reported according to the experience of the research exchange through an analysis of the perspectives reflected in students' written work. We then discuss elements critical to enhancing experiential learning in the cross-boundary peer based learning situation, through a review of the adaptive learning of the teachers involved as the exercise was iterated in three countries successively. Our discussion also considers the challenges presented by the exercise. We conclude with some suggestions for adapting cross-boundary peer learning as a means of strengthening and broadening a learning community around development, environment, and natural resource management as a progressive contribution toward meaningful regionalization in the Mekong Region.

Research Exchange

The idea of a student research exchange emerged through Mekong Learning Initiative teaching method workshops, held twice a year from late 2003 at various locations in the Mekong Basin. Academics from three participating universities in Cambodia, China, and Thailand were keen to apply field-based teaching methods and seek ways to enhance knowledge about their neighboring countries among their students. In particular, they saw the potential for a multi-cultural learning environment involving students from their three universities to give students direct experience of fieldwork outside their national contexts within the Mekong Region. The discussion among the three universities and University of Sydney (facilitator of the Mekong Learning Initiative) thus led to a research-based teaching exchange project that applies innovative teaching methods to address common themes relevant to the Mekong. First, students would learn about linkage of national policy to livelihoods at the community level through inquiry-based approaches instead of through the more passive learning commonly experienced in study tours. Second, students would be responsible for their learning and work together as peer groups with support of instructors. And third, the research-based approach would give students a sense that they are equal in knowledge acquisition through inquiry and sharing.

The learning process was designed into three periods. The first period was a national policy study during which students at each University undertook desk research on their natural resources policy, respectively. The second period was cross-boundary field study that brought students from three countries together to undertake field learning activities. The third period was regional synthesis whereby students returned to their home countries to integrate material from all three field-learning components into a common analysis.

The research exchange project was publicly announced and received applications from students at each university. Students were selected according to their command of English, relevant fields of study, and their commitment to the exchange project. The selected students have varying degree backgrounds. The six Cambodian

participants were enrolled in Royal University of Phnom Penh's Bachelor of Environment Sciences at third year undergraduate level, the six Chinese students were enrolled in Yunnan University's Master of Human Geography course, while the four Thai students included two at Masters level and two at Bachelor level, all enrolled in Ubon Ratchathani University's Social Development Program.

National Policy Reviews: Three Cases

The thematic and empirical subject of the research exchange was policy on decentralization of natural resource management in the three countries. In China students reviewed sloping land conversion policy. In Thailand, students reviewed the water grid policy that was purportedly to bring agricultural prosperity to the poor northeastern region. In Cambodia, students worked on fisheries policy, in the context of the devolution of management to community fisheries under the 2001 Fisheries Law. The policy review approach was designed to enhance the students' understanding of linkages between policy and its implementation that impacts on local livelihoods. It gave both contextually specific topics of field study in each country, and a comparative theme for working across the national cases in the Mekong Region.

At each university instructors held the first session with the selected students and introduced concepts of policy and livelihoods. The students were then formed into peer groups and assigned to undertake desk research on national policy of natural resources management that was selected by the research exchange project. They discussed their plans and assigned each other specialized tasks to collect papers and reports in key areas from library and online sources. The students met regularly to discuss their findings after distributing and reading the collected materials. When they felt that they had sufficient understanding of the policy they began to organize their thoughts into a draft policy brief. Only then was a session held with participation of the instructors. Students presented their understanding of policy content and critiques, and this was followed by discussion facilitated by instructors. Students had to answer, clarify, and discuss questions posed by instructors. Students continued their desk research after they identified gaps and further information requirements. Completion of each policy review took students about six weeks.

The policy reviews were in areas specific to each country, and more specifically relevant to the areas targeted for fieldwork. In China, central government response to flooding in Changjiang in 1998 had resulted in a large-scale program in 2002 to contain environmental degradation, referred to as Upland Cropland Conversion to Forests. Participating farmers received annual compensation of 200 Chinese Yuan per mu (1 hectare = 15 mu, US$1 = 6.38 Yuan, so US$ 470 per hectare) with a length of eight years for conversion of upland cropland to forests. The program had tangible impacts on farmers' livelihoods (Wang and Bennett 2008) in several respects. Farmers would permanently lose their rights to farm certain areas of land, while maintaining rights to use the area as forestland, receiving compensation. This program made for a stark case for students to investigate linkages between land tenure, policy, and livelihoods. It has also provided a window into governance issues by investigating where, by whom, and how the program was implemented.

Within Thailand, Isan (the northeastern region) is discursively represented as a poor and dry region in need of assistance from Bangkok through large scale infrastructure development. To achieve economic development and poverty reduction, the long-standing policy response is to irrigate Isan, reflected in such programs as Isan Khiew, or Green Isan. The Water Grid Project in Thailand was officially initiated in 2003 to triple Thailand's irrigated area (Molle and Floch 2008). This project provides an opportunity for students to explore (1) policy justification and implementation, (2) project impacts on poverty alleviation and local economic development, and (3) local stakeholders' responses to this policy.

In Cambodia, Tonle Sap Lake is a critical part of the Mekong River ecosystem. The lake absorbs 20 per cent of annual flood water from the Mekong and then releases the water to the lower part of the river below Phnom Penh as the flood recedes. Its fisheries provide a major protein source to Cambodia's population (Sokhem and Sunada 2006). In 2001 the Cambodian government

released 56 percent of commercial fishing lots to communities as community fishery lots with support of the Asian Development Bank. One important instrument was to establish community fishery committees at the village level to manage the community fishing lots. This provides an interesting case for students to explore relations of fishery policy and regulation, implementation of decentralization and livelihood impacts at a local level.

Cross-Boundary Field Study

The field studies were organized according to similar procedures at three sites in the Mekong river basin from China's Yunnan, to Northeast Thailand, to Cambodia's Tonle Sap Lake. Students in each component of the field studies included all participating students of the host university, two students of each guest university, one instructor from each of the participating universities and one or two observers from the Mekong Learning Initiative. Each field study took between five and seven days, depending on return transportation time required to reach the communities to be studied. At the beginning of each field study, a one-day workshop was held to share results of the national policy study and to develop a plan for the field interviews. In the morning, students of each university presented their understanding of their national policy, explained what challenges the country faced, and how policy addressed these challenges. The morning session was open to other students from the host university. It was observed that discussion was vigorous among students. Some questions went well beyond the specific topic of study, extending to social, economic, and political fields.

In the afternoon of this first day workshop, students for the field study were divided into two peer groups consisting of students from three countries. They were assigned to develop a field study plan, which had a clear research question, a specification of what information would be collected from whom, and indicative questions for interviewing different categories of informants such as householders, community heads, and local officials. Each group received comments and questions of clarification from fellow students as well as instructors after they presented the field study plan.

During the first two days of field study, students interviewed various stakeholders such as local officials, community heads, and householders of different economic status. There was no pre-assigned sequence of stakeholder interviews. Local officials often first presented their situation, current programs and outcomes and were then interviewed by students with a set of probing questions. At the community level, students first met and interviewed community leaders, and then interviewed householders selected by community leaders according to the self-set criteria of their field study plan. At the end of each day peer groups were requested to hold a short meeting to reflect their thoughts and identify information gaps. The third day of the field study was reserved for peer groups to discuss findings, analyze the information, and write a three-page report. In the late afternoon, each peer group presented its findings and clarified questions posed by the other peer group. Students then reflected on their field studies, facilitated by instructors. At the end of the field study each peer group completed and submitted a three-page report.

The main criteria to select field study sites included accessibility, observable policy impacts, and the level of local support for students to conduct such an exercise. In Yunnan, the two studied villages are located in steep parts of the Yangbi River subcatchment, a tributary of the Lancang River (upper Mekong). They have an easily accessible road from Dali, a famous tourist spot in China. The Upland Cropland Conversion Program had been implemented here for 2 years. In northeastern Thailand, the two study villages were formerly resettled from the Sirindhorn Reservoir and were pilot project sites of the National Water Grid Project. It takes four hours to reach these two villages from Ubon Ratchathani town. In Cambodia's Tonle Sap Lake, the two study villages are floating villages that are highly susceptible to changes in fisheries policy. They are accessible by boat from Kompong Luong.

Regional Synthesis

A regional synthesis process was implemented at each university respectively. After each field study, a sharing session was held to share experiences. Students who participated presented

their impressions, feelings, and experiences about the field studies. Students then discussed their cross-boundary learning of policy implementation and its impacts on livelihoods. The students were requested to compare the similarities and differences of two countries – their own, and the one just visited. They also reflected on the learning process, discussed which learning activities had been most useful, and suggested improvements for future field studies. Two sharing sessions were held at each university.

Chinese students held two sharing sessions after visiting Thailand and Cambodia. The first impressions that students who visited Thailand shared with their peers were of a general nature, for example observation of Buddhist practices and driving on the left. Students realized that the "water grid project" is a kind of irrigation system and may not automatically benefit the poor. The water grid project had been criticized for its potential impacts in terms of agricultural production, with serious economic and environmental implications. People living in the project area did not have sufficiently fertile soil to grow high quality products and only higher income people who had bought land close to the project infrastructure were able to invest in land and water. Some poor families had sold their farmland and had seasonal jobs in Bangkok. Regarding their experience of Cambodia, two students briefed their peers on the experience of Phnom Penh, Tonle Sap Lake, and Angkor Wat, including excitement at eating insects from street stalls! More substantively, they reported on the extreme dependence of floating villages in Tonle Sap Lake on fishing, with few other choices to making a living.

Cambodian students organized two sharing sessions at the Royal University of Phnom Penh after visiting Yunnan in China and Ubon Ratchathani in Thailand, respectively. Like their Chinese counterparts, the Cambodian students who visited Thailand recognized that irrigation is crucial to farming in the area visited and that the water grid project could benefit villagers if they depended on farming for their livelihoods. However, they also observed that its implementation failed to take account of the local situation and farmer concerns, particularly as most income in the area came from off-farm activity. Students who visited Yunnan in China realized that the program of converting upland cropping into forests follows a clear and nation-wide policy with standard payments to compensate farmers for losing use rights to farm certain areas of land. Under this program, the government of China provided incentives for local people to reforest as a means to conserve water and curtail soil erosion. The Cambodian students felt that the incentive approach with subsidies might become a burden to governments.

Thai students organized two sharing sessions after visiting China and Cambodia respectively. Staying overnight at the floating village, visiting other fishing communities and interviewing local authorities in Tonle Sap Lake of Cambodia left a deep impression on the Thai students. In particular, they recognized for the first time the complete dependence of the villagers on the fishery and their vulnerability if the Tonle Sap fishery were to decline. In China, climbing up the hill to visit the Upland Cropping Conservation Program of Yunnan gave them a sense of connection with local Chinese villagers whose lives and livelihoods had been completely unknown to them before the visit. Students were impressed by ways in which local development had been influenced by government policy, and it seemed to them that locals accepted the policy. Nevertheless, the students continued to wonder whether top-down policy could really benefit local people, and they were also concerned about the sustainability of this policy.

These sample reflections show a number of things about the learning process. First is that students' most lasting and deepest impressions from their exchange visits concerned aspects of everyday life, particularly those which were unfamiliar to them in their respective home country contexts. Second, students understood each local situation through their own interpretive lenses, so that Thai students, for example, maintained a scepticism about central government policy in Cambodia and China, while Chinese and Cambodian students saw Thailand's water grid as a genuine attempt to provide irrigation benefits for the poor, but which had shortcomings in its failure to meet real local needs. Third, it was the visceral experience of the field visits that most affected students, whether it was the harsh conditions of fishers at Tonle Sap or the experience of trekking

to a steep upland community. The policy analysis framework set by the program's instructors was, in this respect, only a secondary means through which to shape students' individual take-home learning experiences, which meant that the reflection and sharing sessions were fundamental in putting these experiences back into an analytical framework relevant to the research exchange's pedagogic objectives.

At the end of this research exchange, participating students at each university were assigned to write a report comparing the three field studies. Students were first organized into their peer groups again to discuss the report outline. With lecturers' assistance, students developed report outlines that consisted of regional policy introduction, country cases, comparison or analysis, and conclusion, then divided their responsibilities accordingly. It was planned that each student would complete their part and come together to write the comparison and conclusion together. However, the final synthesis was not completed as planned. The causes of this are considered in the discussion section below.

Learning Outcomes Reflected in Students' Written Work

This research exchange aimed to enhance students' conceptualization of natural resource policy and rural livelihoods, to help them gain understandings of the linkages between them, and to enhance their comparative understanding of the Mekong through the lens of natural resource management policy and its implementation. The following review reports the learning outcomes against our aims by drawing mainly from the three-page report of each peer group and individual student reflections.

Student projects clearly helped them develop wider and deeper understanding of policy and its implementation. One peer group framed its research question into "What are the local stakeholders perspectives on the Community Fisheries (CF)?" They interviewed fishery officers, an environmental officer, CF committee, four villagers, and held a focus group discussion. After analyzing their findings, reasoning, deliberating, and debating, the peer group concluded:

> The concept of community fisheries is different among stakeholders, especially local people. Most local authorities including fishery officers, environmental officers and community committees seem to have a positive view of CF, but even they don't know how CF will succeed without the support of the Asian Development Bank. The CF committee doesn't understand clearly what the concept of CF is. The CF in their perspective is just like a way to empower themselves to manage fishery resources. In fact they don't know how to use their power as fishery communities. Local community members have a different perspective on CF. Some people have positive, some have negative and others have no idea about CF. The perspective of local people is different from the concept of CF. Community fisheries cannot be a success if local people have a different perspective of the concept of CF.

The peer group attributed these different perspectives to lack of participation from community members, insufficient financial resources, no coordination with NGOs, unclear boundary maps, lack of a strategic plan, insufficient dissemination of CF-related information to local people, and low education/skills of CF committee and local people. They also implied that conflicts and imbalance of power exist. "The people who have a negative perspective on CF say it has not provided them with any benefit since they started. Secondly, CF committees have corruption with lot owners. Third, CFs benefits only people who are better-off." The peer group argued that community fishery policy cannot be successful if local stakeholders have different perspectives from one another.

Students acquired understanding of the concept of livelihoods within specific local contexts rather than as an abstract notion. For example, after the Yunnan field study one peer group described livelihoods of the visited communities as:

> People from both high areas and low areas rely on agriculture. They plant different crops in their farmland because of environment restrictions. Corn is planted in

> the high altitude and rice is grown in the low areas. People in low areas get income from tobacco and those who live in high altitude make a living from walnuts. Life is hard for people living in the upland areas. Poor infrastructure and poor soil quality lead to the poverty in this place, together with lack of education and skills. This area is far from the market and the road to this village is in bad condition. It is hard for people to transport their products to the market. Additionally, because people there aren't educated and lack skills, they cannot get high yields from their farmland and walnut trees, making their lives more difficult.

Students were also able to relate the concept of livelihoods to other variables such as location, crops, and infrastructure. This lateral thinking, relating livelihoods to other variables, results in concern over policy sustainability, in that the project provided people with support for only a few years so it is hard to estimate whether people will keep their forests or change them back to agriculture after the government stops providing them with money.

Students also developed capability to comment on the effectiveness of policy. In Thailand students visited resettlement villages that had farmed infertile rice fields without access to water. One peer group commented on resettlement policy and on the water grid project as follows:

> Resettlement areas don't have good soil and also lack the water system from the river, which they had prior to being resettled. In the past, they lived in low-land areas which are full of fertile soil and waterways around which to base agriculture or other plantations, such as rubber or cashew trees. Villagers are resettlement people, the people who moved from the reservoir of the dam to live in this place. They aren't willing to pay the full water-price in (Village A); or if they pay, they want to pay a low price (Village B). This is because they think the government should encourage them by providing the water for free. Villagers' lifestyle of this generation has been changed and they don't want to invest over a long time in order to receive benefits from farming. For example, the adults prefer going to the big city or foreign countries to find new jobs, so in the village it is just the old and very young people left, those who can't provide enough labor to do the farming.

The peer group identified that policy failure resulted from water pricing, and the fact that irrigation provision neglected to take into consideration agrarian change (i.e., a move out of agriculture) and daily life pressures. They also argued against the necessity of the project in a situation in which most people of (Village B) have sold their farmland. They have no land for agriculture. These people live from fishing or by selling their labor. They don't need the water. However, they also recognized the limitation of their field study and stated that if this policy takes place in another area, not a resettlement area, it might run more smoothly, especially for richer people who can invest money in agriculture.

The research exchange confirms the potential for cross-boundary experiential learning to help students to transform themselves in terms of adaption to and appreciation of different culture and awareness of differing value systems, recognizing their own limited perspectives (Myers et al. 2005). It also gives them skills in understanding different perceptions of the same phenomena by people from different backgrounds (Connell 2006). Students obtained different impressions and concepts about peoples and the Mekong. "After my coming back to China, I have the new idea about Mekong River." "Mekong is not only a river, but it's a region as well." Others were more affective: "It is common to find the people along the Mekong are honest and ardent, just like the mother river's character" and "I smell the fragrance of the exotic culture and really like it" or introspective: "I have found lots of shortages of mine but still find my own strengths, both of these make me more rational and confident."

Most students stated that the project provided a good opportunity for them to enhance their knowledge, skills, and experience of different learning environments. "I can learn and exchange something(s) are different from my country and

improve English language for me." There is also an important social dimension to the students' sense of achievement: "I am very excited to make so many friends in different countries. I really cherish the happy time we spent together this year, especially when we conquered one obstacle and work out our task." Another student observed that "after expressing our ideas, we can get good some recommendations from the students in others countries."

The research exchange cultivated some students' interest in policy and livelihoods. "The research makes me more and more interested about the government policy relating to the natural resource management that effect to local livelihoods." They recognized that if "policy (is) suitable for the local people, (it will be) useful for improving their livelihood." One student claimed that "studying at school just explain(s) what the policies (are), but it does not tell us why a specific policy is made and how it affect(s) the local livelihoods."

Discussion: Reflecting on the Learning Process

In this section we examine elements critical to the effectiveness of cross-boundary peer learning. We evaluate cross-boundary peer learning as the intersection of the three pedagogic approaches (cross-cultural learning, peer learning, and experiential learning) rather than individually. Our evaluation is drawn both from students' reflections, including those in the previous section, and our own observations as instructors.

An important starting point for cross-cultural peer learning is that there needs to be a framing issue around which students study and interact. Establishing a conceptual basis for study facilitates communication and comparative discussion within each cross-cultural peer group. The key concepts in our case were natural resource management policy, rural livelihoods and the impacts that policy has on livelihoods. The participating students brought with them to the field study diverse understandings on concepts of policy through their respective national policy reviews.

The learning challenges tended to emerge when concepts were applied in real-world contexts. For example, the students encountered difficulty when they designed their field study in Yunnan, regarding the delimitation of livelihoods. Questions posed in early discussions such as: "Is income (a part of) livelihoods?" "Should we assess all farming activities?" illustrate the difficulty resulting from a lack of basic understanding of livelihood concepts.

Intensity of interaction within each peer group depended on students' knowledge and cognitive level of the issue to be studied. Piaget (1971) suggested that knowledge is acquired when cognitive stability is directly challenged. In this case study, each peer group consisted of students from three countries, in each of which differing conceptions of policies, role of state versus society, and cultural values were brought to bear. A nervous student asked before the field trip, "Do I have to explain Chinese forest policy to other countries' students?" The student anticipated a situation in which each student of a peer group had to prepare to explain and share his or her knowledge and thoughts. This also served as a challenge to motivate them to advance their conceptualization of the issue to be studied and to brief themselves thoroughly through their home-country policy reviews. "I had to explain our fishery policy to my peers many times," a Cambodian student reflected. This statement demonstrates that significant interaction and negotiation occurred in peer groups. This interaction helped peer groups establish a collective understanding of the issues under study. It was observed that the learning was enhanced by exchanges between students with different degrees of knowledge of forest, water and fisheries policy.

Basic inquiry ability is another element helpful to enhance learning by probing and processing experiences. Three sets of inquiry skills were identified in this case study. The first ability is to translate research questions into interview questions. It was found that students initially encountered difficulties in differentiating research questions from interview questions posed to different stakeholders. When peer groups presented their field study plans, it was clear to us that research questions became interview questions, such as "what impacts do you think policy has on your livelihoods?" or "how did the policy change your livelihoods?" Only with critique and facilitated discussion on the part of the instructors did students break these up into questions more immediately relevant to interviewees' lives

and cognitive understanding. The second ability is to design and conduct interviews. It was a common mistake that students designed and asked leading questions and closed questions, such as "Is the community fishing lot good for you?" "does crop upland conversion have a negative impact because you lose your farmland?" The third ability is to interpret information collected. We observed that students often repeated exactly what interviewees told them with little analysis and interpretation. If the quality of experiential learning results from transformation of experiences (Kolb 1984), we then argue that basic inquiry ability can help acquire and transform experiences. Such prior ability was not considered a prerequisite for students to join the research exchange, but one of our lessons is that it needs to be given constant attention by instructors during the learning process.

Provoker, supporter, and monitor have been identified as roles of instructors (Scheurman 1998). As provokers, we challenged students' field study plans, findings and conceptions when they presented their work. It was at this time that students' cognitive stability was challenged and then re-established after peer groups made an agreement. As monitors, we had to learn the status of peer groups in terms of information collection, interaction, level of understanding, difficulties faced, and then preparedness to be responsive. It was also important to police students to follow schedules, complete tasks and pose reflective questions. As supporters, we provided frameworks or analytical tools that students could try to apply to deal with problems. Most of the time students worked with their peer groups without our intervention. Only when students approached us did we discuss with them by clarifying their questions or sharing additional information or other cases that students could compare with their current case. We also summed up ideas at the end of plenary sessions after students' own discussions.

Appropriate assignments or outputs make peer group work a more active engagement for all participants. Clear output is regarded as a catalytic device that helps a group to converge its energy toward the output that can be regarded as feedback for further action (Kayes et al. 2005). Assignments of presentations and reports were useful instruments to stimulate group work. National policy presentations motivated students as peer groups of the host university to collect and share information, and organize their collective understanding of policy into presentations to the visiting students. The field study plan presentation quickly drew students of the three universities together and focused their effort on the development of the plan. Students psychologically felt that the field study plan became a scaffold to guide their peer group to deal with uncertainty. The three-page report on the field study and presentation created a situation in which each peer group interacted intensively to conceptualize information collected. It was observed that students re-read their notes, analyzed, reasoned, deliberated, negotiated, and agreed to what they should or should not write in the report. However, the daily short peer meetings did not work well, except one when all students stayed overnight at a floating school building in one of the Tonle Sap Lake communities. Elsewhere, students either explored the city or town where they stayed or had fun as a social group, which of course enhanced the cultural experience of the exchange.

We also found that it is difficult for peer groups without common experience to conduct a joint study of regional integration. The intention was to enhance students' understanding of resource governance issues through integration of policy making, implementation, and their impacts on local livelihoods at the regional level. The integration exercise was intended to help students develop an ability to abstract, generalize, and conceptualize experiences of the research exchange. However, the method this study took neglects the requirement of common experiences. Students from each university formed a national peer group. However, the students in each national group did not have much by way of common experiences. For instance, among the six Chinese students, two of them visited Thailand and another two went to Cambodia and the remaining two were without foreign visit experiences. Second, this kind of assignment requires strong academic ability and a great deal of time to complete. Last, students were less motivated to undertake this synthesis as a group project than they might have been if

they had been assigned as an individual to write a reflective report to compare two case studies that they experienced.

The lecturers have identified three key challenges if a similar exchange program were to be repeated. First is English proficiency of participating students. Each of the six countries in the Mekong region uses a different national language, namely Khmer in Cambodia, Lao in Lao People's Democratic Republic, Chinese in China, Thai in Thailand, Vietnamese in Vietnam, and Burmese in Myanmar. English is the common language for academic communication among the six nations. However, there are varying levels of English proficiency among students in the Mekong Region. In this case study exercise, students faced difficulties to communicate, describe, present, and articulate in English. It made it even more challenging that much of the relevant literature is in English, especially in Laos and Cambodia. Language will impede many students to access information as well as participate in regional activities. Selection of students with a high level of English competency would take a higher priority in future selection processes.

The second challenge is the financial constraints of students. Cross-boundary experiential learning is valuable to students, but also costly relative to the current income level of the Mekong region. Meanwhile, most regional universities have constrained budgets and are not able to finance this kind of exercise. Only a few universities and students can afford cross-border immersion activities such as this, and alternative financing mechanisms or less costly operations must be sought out. On the other hand, the cost of the exercise is relatively modest compared to the large number of high-profile, elite-oriented regional integration programs supported by country governments, development organizations and NGOs, and we suggest that this sort of activity is a very cost-effective investment in "regionalization from below."

The last challenge is that there is no institutional agreement or arrangements for universities to transfer course credits with one another. While credit transfer constraints makes cooperation difficult for full-scale exchange programs and joint courses, a practical solution is for participating universities to design a common course based around the exercise described above that can be implemented jointly but credited separately by each university.

Conclusions

The Mekong is undergoing a rapid pace of regional integration, on the one hand, while university students lag far behind in terms of their knowledge and understanding of regionalization on the other. There is an urgent need to bridge this gap. The case of the research exchange described in this article illustrates that cross-boundary field-based teaching in the mode of peer learning is an effective way to offset the knowledge gap, build a shared knowledge base and cultivate positive and nuanced attitudes to regional cooperation.

Teaching the Mekong through a cross-boundary peer and field-based approach has proven to be effective, but there are continuing limitations and room for improvement. Selection of students from a wider base can help tackle the language barrier. Careful selection of field sites and proper course design can significantly reduce costs without compromising the high-quality learning environment. Courses can be jointly designed and independently implemented at each university to solve the problem of credit transfer.

Cross-boundary peer and field-based learning has an obvious advantage to generate common understanding on issues that transcend national boundaries, even within the constraints of the limited period available for field study. Peer groups work together closely to plan the field study, collect information, and analyze the collected data. Most academic learning and analytical skill development takes place within the peer group rather than in the direct field experience. Finally, as each peer-group member is a representative of her or his respective country and culture, the peer-based learning approach is also an instrument to cultivate the sense of belonging to a region.

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References

Australian Mekong Resource Centre. 2007. Regional Economic Integration and the Poor. *Mekong Brief*. Sydney, Australian Mekong Resource Centre, University of Sydney: 4.

Boud, D., R. Cohen, and J. Sampson.1999. Peer Learning and Assessment. *Assessment & Evaluation in Higher Education* 24(4): 413-426.

Connell, J. 2006. I Can't Eat That, It's Purple: a Geography Field Course in Vanuatu and Fiji. *Geographical Research* 44(1): 17-27.

Goldschmid, B. and M.L. Goldschmid. 1976. Peer teaching in higher education: A review. *Higher Education* 5(1): 9-33.

Hirsch, P. 2001. Globalisation, regionalisation and local voices: The Asian development bank and rescaled politics of environment in the Mekong region. *Singapore Journal of Tropical Geography* 22(3): 237-251.

Hirsch, P. and K.M. Jensen. 2006. *National Interests and Transboundary Water Management in the Mekong*. Australian Mekong Resource Centre and Danida.

Kayes, A.B., D.C. Kayes, and D.A. Kolb. 2005. Developing teams using the Kolb Team Learning Experience. *Simulation & Gaming* 36(3): 355-363.

Khaosa-ard, M. and J. Dore (Eds.) 2003. *Social challenges for the Mekong Region.* Chiang Mai, Chiang Mai University.

Kolb, D.A. 1984. *Experiential Learning: Experience as the Source of Learning and Development*. Englewood Cliffs, NJ: Prentice Hall.

Lebel, L., J. Dore, R. Daniel, and Y.S. Koma (Eds.) 2007. *Democratizing Water Governance in the Mekong Region*. Chiang Mai, USER and Mekong Press.

Molle, F. and P. Floch 2008. Megaprojects and Social and Environmental Changes: The Case of the Thai "Water Grid." *AMBIO: A Journal of the Human Environment* 37(3): 199-204.

Myers, D.N., M. Hill, and S.A. Harwood. 2005. Cross-Cultural Learning and Study Abroad: Transforming Pedagogical Outcomes. *Landscape Journal* 24(2): 172-184.

Oehlers, A. 2006. A Critique of ADB policies towards the Greater Mekong Subregion. *Journal of Contemporary Asia* 36(4): 464-478.

Piaget, J. 1971. *Science of Education and The Psychology of The Child*. Translated by D. Coltman, Landon, Longman.

Russell, A. 2005. No Academic Borders? Transdisciplinarity in University Teaching and Research. *The Australian Universities Review* 48(1): 35-41.

Scheurman, G. 1998. From behaviorist to constructivist teaching. *Social Education* 62(1): 6-9.

Sokhem, P. and K. Sunada 2006. The Governance of the Tonle Sap Lake, Cambodia: Integration of Local, National and International Levels. *International Journal of Water Resources Development* 22(3): 399-416.

Topping, K.J. 2005. Trends in Peer Learning. *Educational Psychology* 25(6): 631-645.

Wang, X. and J. Bennett. 2008. *Policy analysis of the Conversion of Cropland to Forest and Grassland Program in China*. Tokyo, Japan, Springer.

Wilson, A.H. 1982. Cross-cultural experiential learning for teachers. *Theory Into Practice* 21(3): 184-192.

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An "IGERT" Model for Interdisciplinary Doctoral Education in Water-Related Science and Policy

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Abstract: Most doctoral programs in the U.S. remain "stove-piped" in traditional single-discipline fields, while scientific progress increasingly occurs at the boundaries between multiple disciplines. In response, the U.S. National Science Foundation has been funding projects in Integrative Graduate Education, Research, and Training (IGERT) to train a new generation of interdisciplinary scientists. The IGERT Ph.D. program in "Watershed Science and Policy" at Southern Illinois University (SIU) builds each year's student class as a diverse "cadre" who work intensively together on one hot-button river basin. The structure of these projects, and other program elements, are reviewed here along with successes and challenges to date. One challenge is the seeming tradeoff between (1) the development of tightly focused expertise versus (2) the breadth that characterizes interdisciplinary research. We conclude that interdisciplinary scientists must have disciplinary depth, but so too should they be trained in collaboration and integrating their results to address the challenges that face today's complex world.

Keywords: *Watersheds, doctoral education, interdisciplinarity*

What is IGERT and why? "IGERT" is the U.S. National Science Foundation's (NSF's) flagship program for fostering interdisciplinary doctoral education. The acronym stands for "Integrative Graduate Education, Research, and Training," and these terms succinctly capture some of the key goals of the program. Traditional graduate education, and much of NSF's budget, involves research and related activities within single scientific disciplines. Water-related research occurs within at least seven different NSF Directorates: Biological Sciences; Computer and Information Science and Engineering; Education and Human Resources; Engineering; Geosciences; Mathematical and Physical Sciences; Social, Behavioral, and Economic Sciences (NSF 2011), and numerous different programs within each of these Directorates. Graduate education, probably not coincidentally, largely follows the structure of research funding, with degrees, coursework, and research typically following one single disciplinary track. The problem with such a discipline-specific model, it's been suggested, is that a growing proportion of cutting-edge scientific questions and applications now occur at the boundaries and areas of intersection of multiple traditionally different fields. NSF (2011) advises that successful IGERT proposals "should provide a framework for integrating research and education and for promoting collaborative efforts within and across departments and institutions. Students should gain the breadth of skills, strengths, and understanding to work in an interdisciplinary environment while being well grounded with depth of knowledge in a major field."

NSF's IGERT program is designed to train top U.S. doctoral students through new educational models that cross the disciplinary pigeonholes that characterize most university science programs. More than just "inter-disciplinarity," the program's goals are education, research, and training that are "integrative." Whereas five researchers from different departments sharing lunch at the same table could be considered "inter-disciplinary," truly "integrative" science implies an activity that purposefully assesses the key elements of a problem and addresses them with information, measurements, analyses, and insights from all relevant fields. For the five researchers above

to have an "integrative" meal, they would need to work together in the kitchen, combining their different and complementary culinary skills into a new fusion menu that none of them alone could prepare. The overarching target of integrative science, and the IGERT program, is research and education in which the sum of the interdisciplinary elements is greater, much greater potentially, than the summed problem-solving potential of their disciplinary parts.

NSF seeks to spark integrative science by funding new IGERT doctoral science programs with student fellowships (stipends and cost-of-education allowances for university fees, textbooks, etc.), student field and laboratory research expenses, student conference travel and expenses, development of interdisciplinary curricula, acquisition of research equipment, and other costs associated with building and running such a "transformative" new program. Allowable program elements are outlined in NSF (2011), although specific details and activities within this structure vary widely from program to program. In addition to the basic structure and elements of most IGERT programs, NSF further recognizes "that globalization of research and career opportunities require students to acquire an international perspective [which] may be gained through … collaborative research experiences and/or fieldwork at foreign institutions and sites" (NSF 2011). Universities applying to the IGERT program may request supplementary funding from NSF's Office of International Science and Engineering (OISE), awarded competitively, in order to weave meaningful international research activities into the broader IGERT program fabric. In addition, a new opportunity (implemented after the SIUC IGERT program was funded) provides "Competitive Innovation Incentive Funds," for enabling and encouraging technology transfer by student trainees (e.g., prototyping costs, pilot studies, and patent filing fees; NSF 2011).

Need for Interdisciplinarity in Watershed Science

The late 20th century brought a new era in water-resources management, emphasizing collaboration and involving stakeholders in consensus-building and adaptive management. In a 2002 letter from the American Water Resources Association (AWRA) to President Bush, AWRA identified problems including: conflict among municipal and industrial water users and environmental requirements, 470,000 km of rivers and streams assessed by EPA that do not meet water quality standards, and impairment of 44 percent of estuarine areas in the U.S. The American Society of Civil Engineers' (2009) Report Card for America's Infrastructure graded the conditions of our dams, drinking water systems, and wastewater facilities as a "D." The importance and need for multidisciplinary scientific input to watershed issues is further highlighted by the large number of National Research Council panels currently and recently convened to address national river-basin challenges: the Colorado River basin (NRC 2007), the Mississippi River and Basin (NRC 2004a; 2005; 2008a; 2009), the Missouri River Basin (NRC 2002; 2011), the Klamath River Basin (NRC 2004b; 2008b), the Columbia River Basin (NRC 2004c), the Platte River (NRC 2004d), the Florida Everglades (NRC 2003; 2005b), and many other river- and basin-related studies.

Recent survey data (Bourget 2006) show that traditional single-discipline graduate education has failed to provide the type of professionals needed to meet the diverse and complex issues of water and watershed management in the 21st century as outlined by the National Research Council's (1999) New Strategies for America's Watersheds. NSF's 10-year outlook (NSF 2003) in environmental research and education highlighted the "demand for collaborative teams of engineers and natural and social scientists that go beyond current disciplinary research and educational frameworks." Instead, this new era demands inter-disciplinary approaches that integrate scientific research with resource management and policy-making, with the goal of creating science-literate leaders and policy-literate scientists for placement in government, academia, and the for-profit and non-profit private sectors.

Current issues in water, rivers, and watersheds are among the most cross-disciplinary of any science or scientific applications today. Our group at Southern Illinois University agreed from the start that the broad need for interdisciplinary, integrative science in water-related issues was well matched to the research and educational goals of NSF's IGERT program. Indeed, research groups at other universities also recognized this same need, and several water-related IGERTs have been funded in recent years. In addition, a similar, multi-institutional river- and watershed-focused doctoral program – the Erasmus Mundus

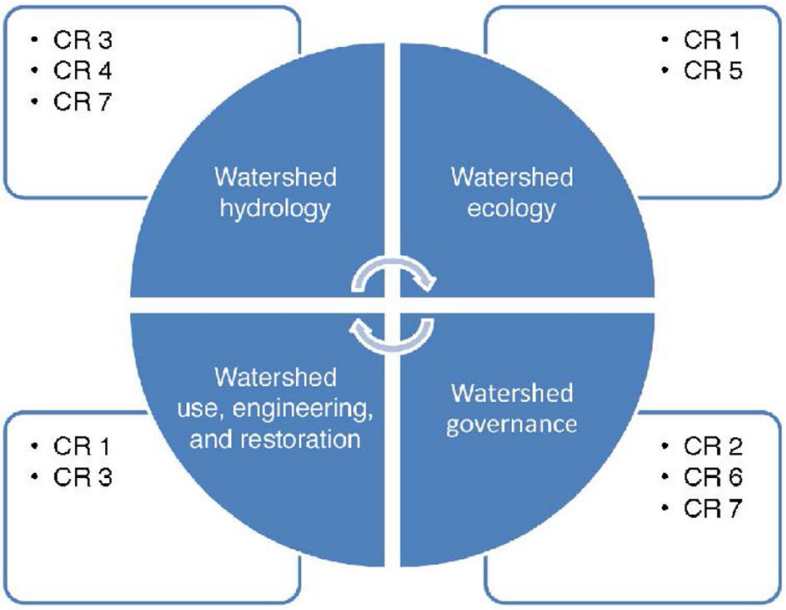


Figure 1. Research and applications in the areas of watershed science and policy cut across many different disciplines, including the four categories schematically grouped together here. The SIU IGERT program identified seven Core Research (CR) questions. Addressing these questions in meaningful ways, we contend, must draw information and insight from many, perhaps even all, of the relevant areas of watershed science.

SMART ("Science for MAnanagement of Rivers and their Tidal Systems; http://www.riverscience.eu) program – has also been implemented by the European Union.

The SIUC Watershed Science & Policy Ph.D. Program

The SIU IGERT program identified seven core research (CR) questions that cross-cut the many different disciplinary approaches to, and applications of, watershed science:

CR 1. How can the ecological health of watersheds be objectively assessed and related to the dynamics of physical systems and human impacts upon them?

CR 2. How do demographic and economic forces, legal frameworks, policies and practices at state, national and international scales influence on-the-ground and in-the-water conditions in watersheds?

CR 3. How do we document anthropogenic impacts on river and watershed systems and then set socially and economically viable biological, ecological, and geomorphic benchmarks for rehabilitating those systems?

CR 4. Can engineering modifications of natural systems be designed to maintain sound physical dynamics and the effective delivery of ecosystem services, including provisioning services?

CR 5. Under what circumstances of local culture, human capital, social networks, institutional capacities, and physical settings do effective and locally significant watershed governance institutions develop?

CR 6. How can watersheds be better governed on the basis of scientifically-sound, participatory watershed planning and adaptive management?

CR 7. How can models be constructed that capture nature-society interactions in a space-time framework to help guide watershed management and policy development?

The structure, curricula, and research activities of our IGERT program have been designed to help answer these questions by promoting doctoral education, research, and training that helps lower the barriers between traditional watershed disciplines.

Program Structure: The premise driving the design and structure of the SIUC IGERT program has been that student training in multidisciplinary watershed science cannot be meaningfully multidisciplinary without meaningful collaboration between students and advisors from different disciplines. The central approach in this program has been to train each year's IGERT class as a collaborative, interdisciplinary cadre. A "cadre" is defined as: "a nucleus or core group of trained personnel able to assume control and to train others" (Merriam-Webster's Dictionary).

Each year, we admitted 5-7 new IGERT fellows, each from a different disciplinary area, to collaborate as a team in constructing a research-driven assessment and management plan for one river basin. Our three cadres have worked in river basins that increased in size, complexity, and logistical challenges through the duration of this project:

Cadre 1: Cache River Basin – a Ramsar Wetland of International Significance located in southernmost Illinois.

Cadre 2: Atchafalaya River Basin – part of the distributary system of the Mississippi River into the Gulf of Mexico, located in Louisiana.

Cadre 3: Tisza River Basin – located in Central Europe, the Tisza is the largest tributary of the Danube River.

Further details about these systems, and the IGERT research projects in each, are provided below.

Admission of each cadre was a challenge each year, but simultaneously one of the great rewards of participating in this program. Our group recruited heavily throughout the year in order to maximize the size, breadth, diversity, and quality of our applicant pool. In general, the IGERT applicants have been among the best Ph.D. applicants on the SIU campus, and the program has increased the number and quality of applications to all of the participating doctoral programs. Selection of applicants for admission to the IGERT was done by the Principal Investigators (PIs) as a whole and was a challenging multivariate optimization function that attempted to maximize both the quality and the diversity of the resulting cadre. Diversity was a central element of the selection process, simultaneously emphasizing disciplinary background, ethnicity, gender, specific analytical skills, and other secondary factors.

A new cross-disciplinary watershed curriculum was developed at SIU to serve the IGERT program. This new curriculum consisted of three new courses: (1) Watershed Science, (2) Watershed Policy, and (3) Integrative Watershed Research and Internships. The watershed science and the watershed policy classes have been particular successes on campus because they have drawn large audience, serving what appears to have been pent-up demand on campus for multidisciplinary training in these areas. Our new Watershed Science class has been developed and coordinated by Prof. Matthew Whiles in the Dept. of Zoology. This course is a multidisciplinary exploration of watershed science and stream ecology, including lectures and discussions of the primary literature led by faculty members from four different colleges at SIUC (Science, Engineering, Liberal Arts, and Agriculture). Topics range from basics of the physical template, including stream flow generation, channel morphology, and water chemistry, to basic ecological concepts such as quantifying energy budgets and conceptual models of stream continua. More applied issues, such as methods for biological assessment and watershed conservation, are also covered. Students are assigned a discussion paper each week, which is usually a "classic" paper on the topic of the week, combined with related papers in the field.

Our new Watershed Policy class was developed and coordinated by Prof. Christopher Lant in the Dept. of Geography and Prof. Sara Baer in the Dept. of Plant Biology. The class explores socioeconomic driving forces in watersheds from a neoclassical, institutional and ecological economics perspective and how these can be incorporated into integrated watershed models, for example by linking crop prices to land use to soil, C, N, and P retention as an ecosystem service. Principles of the U.S. legal system are presented as the foundation for watershed governance. Finally, these are applied in in-depth case study papers of particularly interesting watersheds, with the IGERTs focusing on the Yangtze which they visited. Our Integrative Watershed Research class was designed to serve

each of our IGERT cadres during the semester when they were off campus, serving internships or otherwise engaged in research in their team's study basin. Profs. Pinter and Chevalier developed a week-to-week schedule of guided readings, data gathering and analysis and, most importantly, a series of milestones to guide each group towards completion of its final collaborative study product.

International Activities: Our group applied for and received a supplement from NSF's Office of International Science and Education in order to weave international research and training into the fabric of our IGERT program. This international element was one of the most appreciated elements of our IGERT, by our student fellows and by the participating faculty as well. Each IGERT student and PI worked in one international watershed, with the culmination of these international activities being our program's project in the Tisza River Basin (see below), during which Cadre 3 will live in Europe for 6 months, working with university, government, and NGO partners in four different countries.

Our first IGERT cadre worked in the Panama Canal watershed, in the end spending a total of 2-3 weeks touring, meeting stakeholders, and gathering data in the region. During their first voyage to Panama, IGERT students examined issues in the watershed from headwaters to the Canal. Students explored the Canal Zone, learning about the history and inner workings of the Canal, as well as the current expansion project and related conservation issues. In the headwaters, students learned about disease-driven amphibian declines, urbanization, and other threats to the integrity of the watershed, as well as challenges to developing ecotourism and related forms of sustainable economic development. The trip culminated in a journey up the Chagres River to an indigenous village, which explored additional benefits of watershed protection, including conservation of biodiversity and protection of indigenous culture. After the original Panama trip in 2011, its leader (PI Whiles) was so frugal that a second trip was schedule in 2012, focusing on re-survey of a long-term study stream that experienced a catastrophic amphibian decline in 2008 and is undergoing suburban development. Along with documenting long-term changes in physical and biological aspects of this stream, comparisons were made with similar streams draining more sustainably developed areas in southern Costa Rica.

Our second IGERT cadre spent two weeks in the spring of 2012 touring, meeting stakeholders, and gathering data along the Yangtze River in China. A particular focus was the interaction between the Three Gorges project, the length of which was explored by ferry boat, and Dongting Lake, formerly China's largest, which was explored by bus and small motorboat. The attenuation of high summer monsoonal flows, combining with incision of the Yangtze channel downstream of Three Gorges, are conspiring to drain Dongting Lake, one of the few high quality wildlife habitats remaining in China. The diversion of Yangtze water to the Yellow River basin and the sinking Yangtze Delta near Shanghai were secondary foci. Led by SIU faculty Dr. Wang Guangxing, students interacted with faculty at Central South University of Forestry and Technology and Beijing Forestry University. Together these international basin activities have significantly enhanced the exposure of our IGERT fellows to watershed-related research questions, tools, issues, and colleagues outside of the borders of the U.S. Although not always possible for every Ph.D. student, we consider such exposure to be a valuable asset in training the next generation of researchers and educators.

Other IGERT activities: NSF allows a range of other IGERT activities to broaden and enrich the education, research and training of the fellows enrolled in an IGERT program. Our watershed program has taken advantage of a number of these opportunities, we feel with significant benefits to our students. Among these many activities, we have brought a number of key watershed scientists and policy-makers to SIU for workshops, field trips, and other personal interactions with our IGERT students, as well as with others on campus. For example, our students did an intensive two-day workshop with David Conrad, Senior Water Policy Analyst with the National Wildlife Federation, who provided readings and guided the group through detailed seminar discussions of several hot-button political and environmental issues. We also hosted Carl Bruch, who is Senior Attorney and Director of International Programs for the Environmental Law Institute. Another major IGERT initiative was the "World Rivers in the 21st Century" symposium that

we convened in Carbondale in November of 2011. Speakers and attendees came from across the U.S., and the event was highlighted by a keynote presentation from Philip Weller, who is Director of the International Commission for the Protection of the Danube River.

In addition to in-coming watershed experts, our IGERT student fellows have travelled to a number of field locations and met with a number of outside experts. Such program travel has included numerous presentations of student research at conferences, meetings with governmental agencies and national NGOs such as The Nature Conservancy, and research and educational trips. Our 3rd cadre, for example, did a two-week trip through the Colorado River basin, meeting with nearly two dozen stakeholder organizations. This trip was part of a watershed research training exercise that the group completed their first summer on campus; both as a team-building exercise and as preparation for their full-blown research project in the Tisza River basin (see below). Other IGERT programmatic activities include funding for external dissertation advisors, with the goal of broadening the exposure of our students outside SIU's boundaries, and a range of other educational and training opportunities.

Team-Based Watershed Research Studies

As outlined above, the centerpieces of the SIU IGERT program were the collaborative studies that each cadre conducted in its study watershed. These studies were our principal mechanism for encouraging – "forcing," even – the multidisciplinarity and integration that are the primary goals of all IGERT programs. The three IGERT study basins – the Cache, the Atchafalaya, and the Tisza – were selected because they posed the range of multidisciplinary challenges that characterize many watersheds. As a group, these basins formed a logical progression for our program, starting relatively close to home and increasing in distance, basin size, complexity, and scope thereafter. All three basins are currently under intense scrutiny – at the regional, national, and international scale, respectively – and all three IGERT cadres have the opportunity to contribute meaningfully to long-term management strategies in these systems.

Cache River Basin: The Cache watershed covers 1944 km^2 of southernmost Illinois, a portion of which is part of the Ramsar Convention and has been designated a wetland of international significance. Geologically, the lower reaches of the Cache River are massively under-fit for their floodplain, the valley of which formed as the ancestral Ohio River during the Pleistocene, until glacial outburst floods rerouted the Ohio to its present-day position. Ecologically, the Cache watershed contains a unique and diverse wetland ecosystem that includes bald cypress (Taxodium distichum) and water tupelo (Nyssa acquatica) swamps, and harbors over 100 state threatened and endangered species.

The Cache River basin is a focal point for ecotourism and conservation efforts in southern Illinois, but it suffers from numerous anthropogenic modifications. Like many watersheds in agricultural regions, the Cache ecosystems are threatened by sedimentation, habitat fragmentation, stream channelization, and diversion. The Cache system was channelized and the upper portion re-routed to the Ohio River in 1911, resulting in radically altered hydrology that triggered severe stream-channel incision that has propagated upstream from the channelized reach into the richest ecological areas. While the upper reaches suffer from incision, bank sloughing, and habitat loss, the lower Cache River has been cut off from its headwaters and thus does not flow during much of the year. During summer low-flow, or in this case no-flow, periods the lower Cache becomes anoxic and cannot support a healthy aquatic community or productive fisheries. Proposals are now being developed to re-connect the river as the centerpiece of an on-going wetlands restoration program.

Our first IGERT cadre began working in the Cache River basin in January of 2011, and they have now completed a sweeping research, management, and policy study of the watershed. Findings of this report focused upon key recommendations for management and continued research in this threatened ecosystem and in ecosystems like it elsewhere in the U.S. The report's conclusions have been embraced by stakeholders, and a number of research publications are now in preparation. To give one example, IGERT student trainees Kristin Bouska and Tim Stoebner have mapped

and measured stream restoration structures in the Cache – a class of structures utilized nationwide, but rarely evaluated systematically – and created a hierarchy of effectiveness metrics to guide stream restoration projects elsewhere. Stream restoration efforts around the country have been criticized for not being based on sound science and ecological principles; the IGERT students working on the Cache have produced and synthesized information that is informing management and restoration efforts in the basin, and this project can serve as an example for similar restoration efforts.

Atchafalaya River Basin: The second cadre of students is studying the Atchafalaya River Basin, a major distributary of the Mississippi River. During the spring of 2012, fellows worked with government agencies and NGOs within the basin: the U.S. Geological Survey, The Nature Conservancy, and the Audubon Society. They are currently drafting an interdisciplinary watershed management plan that, in addition to describing the governance structure and state of current scientific knowledge about the basin, will focus on an ecosystem services decision-support tool. The tool will illustrate the manner in which discharge, under the nearly complete control of the Army Corps of Engineers at the Old River Control Structure to fulfill the basin's raison d'etre of flood control, is functionally related to other ecosystem services the basin provides. These include provisioning services such as navigation and crawfish production, cultural ecosystem services such as game fishing and other outdoor recreational activities, and regulatory ecosystem services such as sediment retention and transport, denitrification, and carbon storage. Each of these services is represented by stakeholders whose alliances and rivalries may conform to the complementary or competitive relationships among the services themselves.

Tisza River Basin: The Tisza River is the largest tributary of the Danube River, and its basin is home to 14 million people in Slovakia, Ukraine, Hungary, Romania, and Serbia. The Tisza watershed is the focus of extensive national and international research and discussions regarding flood control, water quality, and management issues. Following severe flooding in the 1990's and early 2000's, the Hungarian government began a large-scale flood-control project (the "New Vasarhelyí Plan") focusing on construction, rural development, and environmental management. Water quality also has been a major concern along the Tisza, especially following a cyanide spill in 2000 from a gold mine along a Romanian tributary that killed fish and contaminated water supplies far down the Tisza and Danube. In 2010, a large containment pond at another mining facility failed, releasing a red sludge that killed 10 people, caused chemical burns to many others, and contaminated a large area of the Tisza River and its floodplain. The Tisza basin countries produced a joint basin management plan in 2009, and currently are working on new basin-wide water quality standards under the European Water Framework Directive. It has been suggested that some, perhaps many, of today's challenges in the Tisza basin can be traced to its 19th century history, during which most of the lowland basin – the Great Hungarian Plain – was dewatered and the Tisza River disconnected from its headwaters, its basin, its floodplain, and longitudinally as well.

The SIU IGERT program selected the Tisza system as the capstone of its basin studies and of its international activities as well. PI Pinter had worked in the past in Central Europe and initiated a series of national partnerships with the help and under a unifying partnership with the United Nations-based International Commission for the Protection of the Danube River (ICPDR). The Tisza basin was selected because of the breadth of its scientific significance and because of the particular challenges of management of a transboundary river system (in this case, under the umbrella of the ICPDR). The third IGERT cadre is departing for the Tisza in January of 2013, beginning 6 months in residence with partners in four countries: Serbia, Romania, Hungary (at universities in Budapest, Szeged, and Kaposvar), and in Austria (at the ICPDR in Vienna). One of the organizational challenges in this project was how to cover the broad territory of a large transboundary river basin while simultaneously structuring a fundamentally collaborative, team-based project. Our solution is an "inhale-exhale" model, in which the IGERT students will disperse to live and work with their national hosts, but then assemble together and with the PI biweekly for 3-4 days at the "home base" in Budapest. The students will also be taking the "Watershed Policy" class,

together with classmates back in Illinois, using an internet-based teleconferencing platform. And the students' "Integrative Watershed Research" class is structured to lead them through the milestones of completing a multidisciplinary analysis with a tentative title, "Tisza River connectivity: Past losses, present-day dynamics, and future opportunities" – a topic recommended by the ICPDR and local partners as particularly timely and significant.

Successes

The SIU IGERT program has had some successes and has worked through some challenges, both of which we offer up as lessons for other groups who may seek to replicate this kind of multidisciplinary program, or parts thereof. Among the successes, we would highlight progress in (1) interdisciplinarity, and (2) team-based collaboration.

The primary goal of NSF's IGERT program is to break down the barriers between traditional "stovepipe" disciplines and foster education, research, and training that crosses these divides. The experience at SIU is that NSF's investment achieved this goal, not only for the students specifically enrolled in the IGERT program here, but for the participating departments and the university as a whole. Annual evaluation of IGERT students includes a survey administered in the spring semester to assess: (a) achievement of project objectives, (b) development of personal and professional skills, (c) perception of internal and external mentoring activities, (d) perception of international activities, and (e) development of diverse career goals. A reoccurring theme expressed by the IGERT students is the educational benefits of team-based collaboration and networking opportunities available because of international travel and internship opportunities. When students were asked to identify their most rewarding experience and skills gained in the IGERT program, the responses were primarily focused on communications skills or learning to work and collaborate as a team.

More broadly, having the IGERT watershed program on campus has (1) led to new cross-disciplinary courses that instantly fed into a pent-up demand for such interdisciplinary training, (2) forged personal connections among the participating faculty have already led to new research activities, (3) encouraged inter-departmental graduate projects that set new standards for outside-the-box collaborations, and (4) broken down institutional barriers to interdisciplinarity. As an example of the latter, the SIU Graduate School originally had a policy against multi-authored manuscripts being accepted as part of a dissertation. We negotiated a new university-wide policy that appropriately large, collaborative, multi-authored works – including our IGERT teams' watershed studies – would be eligible under the university's manuscript option (≥3 published or publishable papers) for dissertations. This new recognition of the value of collaborative, multi-disciplinary research has opened the way for future students beyond the IGERT program.

The SIU IGERT has also been successful in fostering research collaboration, both among our IGERT fellows and more broadly among the participating faculty and departments. Among the watershed IGERT students, their basin research projects successfully trained each group – from the very start of their doctoral work – to conduct research as an interdisciplinary team, with overlapping expertise and duties, rather than as solitary workers. One anecdote that embodies this experience comes from a multi-day field trip that one of the authors here took with Cadre 1 as the students were revising one of the chapters for their watershed study. During two 4+ hour van rides, the author watched as the students passed a laptop computer back and forth as each of them took a turn iteratively writing, editing, and revising the same document. Although single authors or small sets of coauthors may still be the norm for most scientific papers, a growing proportion of academic research, and a much greater proportion of applied research and applied science, comes from broad team-based efforts.

Challenges

An honest assessment of any IGERT program would certainly acknowledge the considerable challenges of implementing such a project. Here at SIU, some of the challenges we encountered were probably unique to our programmatic theme, program structure, and personalities involved, whereas other challenges probably are inherent to the nature and broad ambitions of any IGERT or other sweeping training project. One cross-cutting

challenge that we have heard from other IGERT PIs is the disconnect between the large efforts required to properly manage one of these programs and the limited compensation that can be directed to participating faculty (limited to 1 month/year salary to the Director only). To be 100 percent clear, IGERT awards are a fabulous boon, and NSF's mandate to direct most funds to students is completely understandable, but this structure does demand very high levels of dedication and altruism from PIs and other faculty. The creative IGERT Director will need to find other allowable mechanisms for incentivizing the very large group efforts required.

Another observation ~two-thirds through the SIU IGERT is the considerable variation in group dynamics and personalities, even with our small statistical sample of just 3 cadres. All of our cadres have been successful to date, but some have adapted to the collaborative research paradigm more quickly than others. One interpretation of this variation is simply the range of different student personalities involved. Feedback from the students also points to style variations among the different cadre advisors, ranging from hands-on guidance to more laissez-faire approaches. We draw no sweeping recommendations or insight from this issue, but rather point it out as a topic for further discussion, and probably not a topic unique to team-based or interdisciplinary doctoral projects.

Finally, at the same time our IGERT program was making significant progress in the areas of (1) interdisciplinarity, (2) collaborative research, and (3) focus on application of results, we have been receiving continuous push-back towards (1) single-disciplinarity, (2) individual work, and (3) emphasis on theoretical research. Some of this resistance probably represents academic conservatism, but some resistance points to real trade-offs in the IGERT approach. Our IGERT students begin their doctoral careers working as interdisciplinary teams, but each student has an individual advisor, many of whom press for time and participation in the "home" department and lab. When our IGERT students sometimes complain about limited time and overlapping obligations, we first tell them "Welcome to life in academia!" But time is limited, and commitment to increased breadth in doctoral education, research, and training probably inevitably comes at a cost of reduced depth in any one particular field.

Looking Forward

NSF's IGERT program seeks to create new models of interdisciplinary doctoral education, research, and training. The goals here are to break down the barriers that traditionally separate individual stove-pipe scientific disciplines and, in so doing, to promote future research that is "integrative" and, ideally, even "transformative." The SIU IGERT in "Watershed Science and Policy" is one element of this transformation, but we have documented tangible successes in steeping our Ph.D. fellows in interdisciplinarity and a team-based approach to scientific research and applications. We have also documented challenges to this transformation, including a seemingly inevitable tradeoff between each student's personal depth and technical focus versus the breadth of their interdisciplinary training. The ideal and difficult solution, we have suggested to our students, is that the new generation of interdisciplinary scientists must each have that disciplinary depth, but they must also be rigorously trained in collaborating with other specialists and together integrating their results in order to address problems that cannot be answered one-dimensionally and provide applications to the broad challenges that face today's complex world.

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References

American Society of Civil Engineers. 2009. *Report Card for America's Infrastructure*, 153. American Society of Civil Engineers: Reston, VA.

Bourget, P. 2006. Integrated water resources management curriculum in the United States: Results of a recent survey. *Journal of Contemporary Water Research and Education* 135: 107-114.

National Research Council. 2011. *Missouri River Planning: Recognizing and Incorporating Sediment Management.* The National Academies Press: Washington, DC.

National Research Council. 2009. *Nutrient Control Actions for Improving Water Quality in the Mississippi River Basin and Northern Gulf of Mexico.* The National Academies Press: Washington, DC.

National Research Council. 2008b. *Hydrology, Ecology, and Fishes of the Klamath River Basin.* The National Academies Press: Washington, DC.

National Research Council. 2008a. *Mississippi River Water Quality and the Clean Water Act: Progress, Challenges, and Opportunities*. The National Academies Press: Washington, DC.

National Research Council. 2007. *Colorado River Basin Water Management: Evaluating and Adjusting to Hydroclimatic Variability.* The National Academies Press: Washington, DC.

National Research Council. 2005b. *Re-Engineering Water Storage in the Everglades: Risks and Opportunities.* The National Academies Press: Washington, DC.

National Research Council. 2005. *Water Resources Planning for the Upper Mississippi River and Illinois Waterway.* The National Academies Press: Washington, DC.

National Research Council. 2004d. *Endangered and Threatened Species of the Platte River.* The National Academies Press: Washington, DC.

National Research Council. 2004c. *Managing the Columbia River: Instream Flows, Water Withdrawals, and Salmon Survival.* The National Academies Press: Washington, DC.

National Research Council. 2004b. *Endangered and Threatened Fishes in the Klamath River Basin: Causes of Decline and Strategies for Recovery*. The National Academies Press: Washington, DC.

National Research Council. 2003. *Adaptive Monitoring and Assessment for the Comprehensive Everglades Restoration Plan.* The National Academies Press: Washington, DC.

National Research Council, 2004a. *Review of the U.S. Army Corps of Engineers Restructured Upper Mississippi River-Illinois Waterway Feasibility Study*. The National Academies Press: Washington, DC.

National Research Council. 2002. *The Missouri River Ecosystem: Exploring the Prospects for Recovery.* The National Academies Press: Washington, DC.

National Research Council. 1999. *New Strategies for America's Watersheds***.** The National Academies Press: Washington, DC.

National Science Foundation. 2003. *Complex environmental systems: Synthesis for Earth, life and society in the 21st Century*. Available at: *http://www.nsf.gov/geo/ere/ereweb/ac-ere/acere_synthesis_rpt_full.pdf.*

National Science Foundation. 2011. *Integrative Graduate Education and Research Traineeship Program Solicitation*. NSF 11-533. National Science Foundation: Washington, DC.

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Environmental Aquatic Resource Sensing: Basic Sciences, Business Education, and Outreach

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Abstract: Freshwater resources are critical features of the landscape and are threatened by many phenomena (e.g., eutrophication, invasive species, climate change, acid rain). The importance of fresh waters requires that scientists continually improve their tactics and technologies for broader understanding. Increasing use of automated sensors to collect environmental data creates a need for training of environmental scientists. In this paper, we present case studies based on a doctoral training program. For each case study presented, the goals and overall recommendations for adaptation to other programs are discussed. Case studies were selected based on recommendations of external evaluators of the program, the perceived value of the particular case study to the overall program, and the desire to provide case studies that were illustrative of the primary objectives of the project. We conclude that training of scientists in this area requires a consideration of the technology behind the sensors, proper usage of this technology, the technology development process, data management, and technology transfer. In addition to sensor-specific attributes of our program, we also have gained insight into the process of professional development for graduate students and how students can work across disciplines and universities. Our key suggestion for achieving inter-disciplinary training is to give students a common problem to tackle and the tools to do so. To ensure that these efforts are successful, identification of a group leader and provision of an opportunity for bonds and relationships to develop is vital.

Keywords: *Sensors, freshwater, technology transfer*

Freshwater resources are critical elements for both global function and human survival. Lakes, rivers, streams, reservoirs, and wetlands fulfill an array of functions both ecologically and economically. Some functions are obvious – serving as sources of drinking water and recreation, as transformers and conduits of ecologically relevant materials, and habitat to a diversity of organisms. Freshwater systems shape our landscape, connecting and integrating our biosphere, serving as "arteries and veins" of the planet (Williamson et al. 2008).

Our dependence on freshwater ecosystems is absolute. Globally, fresh water represents a small percentage (less than 2 percent) of the Earth's surface area; this statistic provides a glimpse into its vulnerability and underlines the need to understand aquatic systems. Beyond these issues, scientifically, aquatic systems represent dynamic and integrative landscape components in which multiple biogeochemical and ecological processes happen in close spatial and temporal quarters.

Threats to aquatic systems (e.g., eutrophication, invasive species, climate change, acid rain) are numerous. Our reliance on the structure and function of fresh waters requires that scientists continually improve their tactics and technologies for broader understanding. New approaches are needed because of the spatial and temporal scales on which changes happen. Historically, most environmental studies focused on a specific range of scales but automated sensors allow a new perspective on biological, geological, and chemical processes of aquatic ecosystems. When applied to ecological issues, sensor networks provide increased spatial coverage and sampling frequency beyond what could be achieved conventionally (Porter et al. 2005). Thus, the field of aquatic science is on the verge of a transformation in which exciting new questions can emerge, and chronic threats

to global fresh water can be better addressed.

The increasingly prominent use of automated sensors to collect environmental data, and address the concerns noted above, creates an urgent need for 21st century training of environmental scientists. These scientists must be knowledgeable about: (1) the design and development of sensors for deployment, (2) hypothesis-driven application of sensors and sensor networks, and (3) management/analysis of the resulting large, complex data sets. The recent emphasis on sensor systems is reflected in national programs (e.g., GLEON, the Global Lake Ecological Observatory Network, NEON, National Ecological Observatory Network, Water & Environmental Research Systems Network), centers (e.g., NSF-funded Center for Embedded Network Sensing), and the literature (e.g., the special issue of Environmental Engineering Science, Vol 24, March, 2007).

Lakes themselves are valuable sensors in the landscape. As the lowest point in the surrounding landscape, they are particularly valuable sentinels of climate change (Williamson et al. 2009). More importantly, advanced sensors are critical for resolving the disproportionate impacts that short-term storm events have on lake ecosystems (Jennings et al. 2012; Sadro and Melack 2012), and can address spatial heterogeneity of lake ecosystems at novel time-scales (Van de Bogert et al. 2012).

As a result of this need, we developed a NSF-funded Integrated Graduate Education and Research Traineeship (IGERT) program to educate doctoral students about advanced sensors for freshwater science. The central theme of this program is: Inclusive, immersive student learning in environmental sensing; from a foundation in ecology and environmental science to sensor design and development to creation of sensor networks to analysis of data sets; accentuated with practical business experiences to develop environmental science professionals equipped for positions in academia, private, or the public sector. By the very nature of this topic and the IGERT program goals, this is an interdisciplinary educational project involving faculty and students from multiple areas of science (biology, ecology, microbiology, chemistry, physics, geology, geography). In addition, our program includes faculty and students from two universities, Kent State and Miami, so working together with individuals at a distant location was another aspect of our program. Baldauf McBride et al. (2009), in a study of science graduate students in a NSF GK-12 project, suggest that interdisciplinary graduate programs of this type are "urgently needed to ensure that future leaders of the scientific enterprise are well equipped with the tools to conduct science as skilled collaborators, to address the key interdisciplinary questions that arise from complex environmental challenges facing society, and to better communicate their science with diverse audiences well beyond their scientific peers." Below, we discuss specific examples from our project including those focused on graduate student training (which we define as acquisition of skills and knowledge for applied purposes related to sensor use and development) and education (which we define as a more general student development not focused on development of a specific skill set).

To organize this article, we are taking a "case study" based approach by highlighting below specific aspects of our program that have proven to be most valuable for achieving our goals. In addition, for each case study we provide insights into the pros and cons of each component and the ease with which the approach could be applied at other institutions. The case studies are discussed in the approximate order in which they were conducted. Figure 1 illustrates the order in which we have covered these topics as well as the format we recommend. Case studies were selected based on discussions with two external evaluators of the program (who interviewed faculty and student participants), the perceived value of the particular case study to the overall program goals, and the desire to provide case studies that were illustrative of the primary objectives of the project.

Case Study 1: Using Unfamiliar Tools to Address Scientific Questions

Specifics of Case Study: One of the central theses to our educational approach is to provide an opportunity for individuals to become quickly immersed in the scientific process using environmental sensors. A secondary benefit of

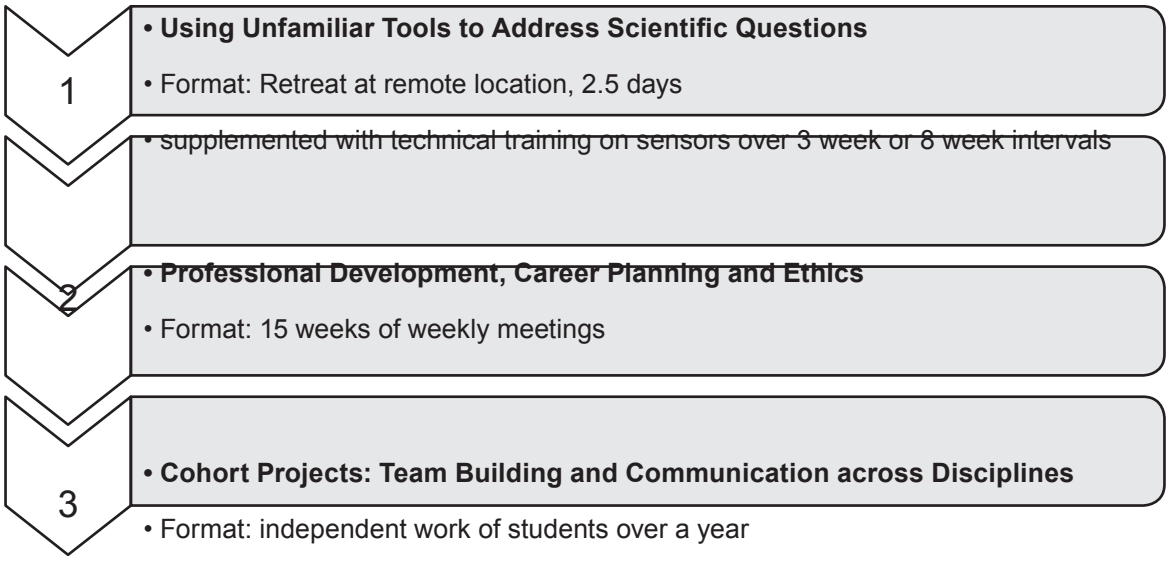


Figure 1. Order in which the various activities described in each case study (1-4) were implemented in our project and recommended format.

this immersion is the chance for students from diverse fields and backgrounds to get to know each quickly, minimizing the chance for distracting misconceptions of other fields to develop. The importance of the theme of this case study is three-fold: team-building, providing hands-on experience with sensor technology, and giving students a chance to ask and answer small-scale scientific questions. To accomplish this goal, faculty and students travelled to a remote field site far distant from our home institutions. This provides a location that is on 'neutral' ground (i.e., not at anyone's home institution) and removes the chance for distraction from day-to-day activities. Field trips are crucial aspects of student experiences in a variety of fields and Skop (2009) suggests that they provide an ideal opportunity to "foster informal interaction among students and faculty." Team building exercises, as described in this example, were among the best practices identified by Meléndez-Ackerman (2011) specifically with regard to IGERT programs.

In our particular case, we selected the Lacawac Sanctuary in Lake Ariel, PA because of specific properties which we argue will be helpful criteria for others in such situations. First, this is distant from our institutions but can be readily reached within a half day's drive. Second, it is located on the shores of Lake Lacawac and provides ready access to a field site with active and prior research (e.g., Tessier 1983; Williamson et al. 1997). Third, the site provides on-location lodging so participants not only work together during the formal schedule, but also interact over meals and after hours. The goals of this activity were (in no-particular order):

1. Team building and learning to work across universities and disciplines.
2. Learning about research of trainees and faculty.
3. Hands on activities with sensors.
4. Students posing and answering scientific questions and presenting their findings.
5. Meetings with assessment and evaluation team.
6. Planning for the remaining year and for future projects.

Below, we describe the manner in which we worked to achieve each goal.

The goal of team-building and learning to work across universities and disciplines is central to all aspects of our program. Thus, this first event helps to lay the foundation for future interactions. Providing a face-to-face opportunity for students to get to know each other and bond means that they will be able to stay in touch more easily after they depart to their respective universities. For our

ice-breaking activity, we have asked students to pair up with the person they know the least about, and then to introduce each other to the group. In this way, people that have never met and might be from different science disciplines can begin to understand the areas of research represented by the group. This exercise then lays the ground work for very short presentations on research interests and expertise given by each participant.

Perhaps the most important activity, after having gotten everyone acquainted, is to charge the students with conducting a short research project using sensors. This gives immediate hands on experience with technology that is not familiar to most participants, and provides them a chance to work towards a common goal. For example, students in several cohorts developed an interest in spatial variability of high frequency measurements of parameters, such as temperature, oxygen, pH, or conductivity. In one year, students examined vertical differences in the lake by deploying sensors at different depths at a single location. In another year, sensors were place is different locations but at a similar depth, essentially exploring different habitats (nearshore vs offshore). During these projects, students were exposed to sensor related issues, such as calibration, logging intervals, power consumption, field deployment, and occasionally technical difficulties (trial and error often being a very effective learning pathway). Collecting data at high frequency challenged the students by exposing them to a data set that was much larger than they might typically be used to handling. Extensive data analysis was limited due to time constraints, but students were asked to derive secondary information from their data, such as estimates of respiration that could be calculated from changes in oxygen overnight. In our most recent workshop, students were given access to a suite of advanced aquatic sensors and asked to document evidence of the response of lakes to recent climate events using vertical profiles of various physical, chemical, or biological factors. Ultimately, the students then presented their findings to the entire group, interpreting the "signals" of change in light, temperature, oxygen, chlorophyll, and other variables with depth in the water column. Since each group sampled a different set of variables, a lively discussion ensued.

While these activities are underway, participants also meet with outside assessors and evaluators who take advantage of the gathering to conduct individual interviews. Lastly, the plans for the coming year are discussed; these are described in more detail below.

Recommendations: Based on our experiences, we believe, for educational programs, that off-campus trips that require overnight travel provide an effective way to jump start a program and to form groups working towards a common goal. Proximity to a study site is also an advantage for studies on aquatic ecosystems. Disadvantages include costs and logistics. For the latter, the distance and time involved does inhibit the willingness and ability for faculty to participate.

Coincidentally, one year we were unable to complete the trip to Lacawac Sanctuary due to extensive flooding causing road closures on our drive to the location. While we were able to accomplish many of the goals by holding the event at Kent State, we felt that some of our goals were compromised, especially the formation of a cohesive group that seemed to have otherwise formed during after-hours activities (e.g., sitting around a campfire as opposed to returning to one's home or hotel room).

Case Study 2: Professional Development, Career Planning, and Ethics

Most of the efforts described in this paper are very much focused on student training that is pertinent to our particular theme. However, we became aware of other vital aspects of graduate student education where our program could further contribute. These aspects include professional development and career planning, as well as responsible and effective conduct of research and teaching. Originally these components were underdeveloped in our program, but as it evolved we included them as significant objectives to be met through two mechanisms. The importance of the theme of this case study is that it focuses on one very central aspect of graduate training, responsible and effective conduct of research, that are widespread in programs of this type.

First, we used a series of university-wide workshops (1-2 hours each) that would appeal to the broadest student audience. Topics of these workshops included applying for fellowships, careers in academia, business, and government, manuscript writing, etc. Each workshop featured a speaker with expertise in a particular area, including those that were recently on the job market.

Second, we unified these experiences into a formal course. The reasoning behind formalization was two-fold. While the informal workshops were effective and very well attended, they were difficult to schedule at a time that worked for students in many different departments. In addition, students were not required to attend and because it was informal there was no opportunity for work outside the meeting. With the formal class approach, we have a set weekly meeting time and students can complete assignments outside of class. For example, they can prepare their CVs and share them with their peers. In addition, faculty have provided us with grant proposals for mock review panels. Other topics include appropriate conduct in the laboratory, issues related to manuscript preparation and submission, etc.

Recommendations: Formalizing these activities provides us more opportunity to ensure each student comes away with the tools they need for their future careers. Invariably, writing and speaking are parts of their futures and we work to provide them these experiences in a content-independent manner. Many content specific classes require, for example, students to write a proposal but likely do not cover the true nature of the funding process or provide examples of successful and unsuccessful proposals that were actually submitted by faculty.

Case Study 3: Cohort Projects: Team Building and Communication across Disciplines

The relationships among the students developed during the off-campus retreat are vital to laying the groundwork for their "cohort" project. The idea is to build upon the model of case study 1 (getting students working together towards a common goal) over a longer time frame to achieve more valuable products. There are two central themes of this case study: having student learn to work across disciplines and conducting inter-disciplinary research. This approach has the added benefit of providing students insights into the conceptual framework and 'way of thinking' about science used by those in different fields. The cohorts are composed of students who entered the program at the same time but who are from different scientific disciplines and universities. In this way, the theme of working across fields and campuses is further reinforced. It is important to note that students have to find common language through which scientific exchange can occur, as discipline-based trainings often set jargon boundaries. For example, the word "director" has a specific meaning for chemistry and physics students, that may not be evident to the other science students. Furthermore, ecology students are often well versed in the differences between a "buoy" and a "sonde." Yet, their distinction is not readily evident to most bench scientists. Thus the cohort-building process forces students to familiarize themselves with the science of their new colleagues, enlarging the breadth of their science base.

Another aspect of the cohort project is to give the students a chance to creatively come up with a project that is related to our theme and that takes advantage of their expertise. We start this process by having students from prior cohorts talk about their experiences and offer tips to the new students. These meetings happen during the initial workshop describe above in case study 1. We then provide opportunities for the cohort to brainstorm, giving them access to faculty who answer questions and help the discussion stay focused, but who do not influence the project design. In this regard, each cohort has "ownership" of their project.

There is a gradient or continuum of inquiry based learning approaches; Bonnstetter (1998) describes this continuum as ranging from carefully scripted work to open, student-driven work. This case study represents the latter end of this spectrum which is described by Lee (2012) as "an inquiry experience, perhaps student designed, through which students acquire content relevant to the inquiry and further develop the skills of inquiry."

The types of projects that have been completed are variable. The first group of students developed an educational web page with support from a sensor-related company. This activity provided

them a means of achieving a goal of public education while at the same time working with a business. The latter is central to one of our themes and is developed more below. This web site is called The Lake Scientist (www.lakescientist.com). Working with a company allowed the quality of the web site to be high and to help make sure it would be maintained over time. The second group of students followed a similar line of reasoning but was less successful in making their materials available to the public.

The third cohort is working on two projects. One group is working on development of a liquid crystal based sensor for microcystin, a cyanbacterial toxin. Another group is working on examination of dissolved organic carbon based on optical properties across a range of aquatic ecosystems.

Recommendations: Group or cohort projects are typical components of educational efforts but can have pitfalls. Perhaps the biggest question we face is: what is the role of faculty in the process? In other words, what is the proper amount of guidance to give the students? A balance needs to be struck between allowing the students full independence and creative license, while promoting a project that extends into the realm of broader impacts for science, education, or personal career advancement. Ultimately, the most important goal is to help make sure that their efforts do not derail and that lines of communication remain open and active. For our own program, cohorts in which there was a single individual with strong leadership qualities were more successful than when the leadership was not clear (more than one leader or no one actively assuming that role).

Case Study 4: Technology Transfer and Internships

Often times, scientists use sensor technology daily but may not be aware of the process that leads up to an invention or development of a new product. However, any time we are working on projects that involve technology there is often technology transfer that underlies the product. In addition, a number of students in our project are in the field of sensor development and the products of their efforts likely include patents. Thus, learning the rights and responsibilities, as well as the mechanics, for protecting intellectual property are vital. To this end, we discuss the requirement to document ideas, communicate novel approaches, and suggest applications. These actions define "inventorship" and become helpful in the assignment of patent claims. The importance of this case study relates not only to understanding invention and entrepreneurship but also serves as carrier preparation for students planning on working in the private sector.

We have approached educating students about the business side of science in two ways: internships and seminar-style courses or workshops. Internships can impact the individual student in a profound, transformative way. While the student may share their experiences with others, the learning potential does not extend far beyond the individual. In addition, not all internship experiences are equally positive. In contrast, seminars and presentations provide a way to provide a more general learning experience to a larger numbers of students.

For internships, the goal of our project was for the experience to be consistent with the career interests of the students. In one case, students worked with a Kent State University (KSU) spin-out company, Crystal Diagnostics. This company uses patented liquid crystal sensor designs to detect bacteria and viruses in real time. Students learned the process of product development and methods of scale-up. Included in their "business-world exposure" are the critical roles of quality control, good manufacturing processes, and regulatory compliance issues. In a second example, Miami University students interned with Fondriest Inc. and NexSens Inc, where they are in the process of developing cutting edge technologies for both mobile buoys and buoys that can do automated vertical profiling with a winch that can be controlled from a smart phone.

Another way to educate students about this aspect of sensors is through visits to companies, seminars and presentations. For example, groups of students visited Crystal Diagnostics and company presidents have presented seminars at our campuses. In addition, we've used university resources to help this process. The Kent State University Associate Vice President responsible

for technology transfer, commercialization and marketing, as well as the university lawyer overseeing patents and copyrights, presented the process by which ideas are protected, especially those coming from academic institutions. This not only accomplishes the goal of exposing students to this process it also gives them insight into the inner workings of the university.

Other individuals have also been tapped to help us meet these goals. These include faculty inventors and faculty within our colleges of business, as well as local entrepreneurs. The use of specific seminars and presentations allows groups of students to learn directly from these individuals.

Recommendations: Our observations suggest that many students and faculty are not familiar with technology transfer and entrepreneurship. Internships provide a great manner to gain this experience but can be very time-consuming and do not necessarily include specific learning objectives, such as intellectual property. Internships also require the institution and its partners to take on additional management responsibilities. Taking advantage of resources offered by the technology transfer office, which most major research universities have, provides a simple way to help meet at least a portion of these educational goals without the time and resource commitment of internships. Our experiences have shown that the missions of the offices involved are very consistent with our educational goals and that they are capable of providing valuable experience and assets to assist in our training.

Conclusions and Recommendations

To describe our inter-disciplinary graduate student training program, we use a case study based approach to highlight specific approaches used to achieve educational goals. Case studies, selected based on criteria described in the text, illustrate the manner (using specific examples) our goals were achieved and provide ideas about the strengths and weaknesses of each example and transferability to other institutions and settings. Our particular program, which focuses on sensors, is built upon the premise that sensors are an integral part of freshwater science and training of scientists in this area requires a consideration of multiple factors: the technology behind the sensors, proper usage of this technology, the process by which new technology is developed, data management, and technology transfer. In addition to sensor-specific attributes of our program, we also have gained broader educational insights into the process of professional development for graduate students and how students can work across disciplines and universities. The key to achieving inter-disciplinary training, in our view, is to give students a common problem to tackle and the tools to do so. To ensure that these efforts are successfully launched, identification of a group leader and providing an off-campus experience to allow bonds and relationships to develop is vital.

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References

Baldauf McBride, B., C.A. Brewer, M. Bricker, and M. Machura 2011. Training the Next Generation of Renaissance Scientists: The GK-12 Ecologists, Educators, and Schools Program at The University of Montana. *BioScience* 61: 466-476.

Bonnstetter, R.J. 1998. Inquiry: Learning from the Past with an Eye on the Future. *Electronic Journal of Science Education* 3.

Jennings, E., S. Jones, A. Lauri, P.A. Staehr, E. Gaiser. I.D. Jones, K.C. Weathers, G.A. Weyhenmeyer, C. Chiu, and E. De Eyto. 2012. Effects of weather-related episodic events in lakes: an analysis based on high-frequency data. *Freshwater Biology* 57(3): 589-601.

Lee, V.S. 2012. What is inquiry guided learning? *New Directions for Teaching and Learning* 129: 5-14.

Meléndez-Ackerman, E.J. 2011. Professional Training and Graduate Education Needs in Warfare Ecology. In Machlis G.E., T. Hanson, Z. Spiric, and J.E. McKendry (Eds.) *Warfare Ecology*, 259-271.

Porter, J., P. Arzberger, H. Braun, P. Bryant, S. Gage, T. Hansen, P. Hanson, C. Lin, F. Lin, T. Kratz, W. Michener, S. Shapiro, and T. Williams. 2005. Wireless sensor networks for ecology. *Bioscience* 55: 561-572.

Sadro, S. and J. Melack. 2012. The effect of an extreme rain event on the biogeochemistry and ecosystem metabolism of an oligotrophic high-elevation lake. *Arctic Antarctic and Alpine Research* 44: 222-231.

Skop, E. 2009. Creating field trip-based learning communities. *Journal of Geography* 107: 230-235.

Tessier, A.J. 1983. Coherence and horizontal movements of patches of *Holopedium gibberum* (*Cladocera*). *Oecologia* 60: 71-75.

Van de Bogert, M.C., D.L. Bade, S.R. Carpenter, J.J. Cole, M.L. Pace, P.C. Hanson, and O.C. Langman. 2012. Spatial heterogeneity strongly affects estimates of ecosystem metabolism in two north temperate lakes. *Limnology and Oceanography* 57: 1689-1700.

Williamson, C.E., S.L. Metgar, P.A. Lovera, and R.E. Moeller. 1997. Solar Ultraviolet Radiation and the spawning habitat of yellow perch, *Perca flavescens*. *Ecological Applications* 7: 1017-1023.

Williamson, C.E., W. Dodds, T.K. Kratz, and M.A. Palmer. 2008. Lakes and streams as sentinels of environmental change in terrestrial and atmospheric processes. *Frontiers in Ecology and the Environment* 6: 247-254.

Williamson, C.E., J.E. Saros, and D.S. Schindler. 2009. Sentinels of change. *Science* 323: 887-888.

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New Learning Foundations for Building Water Knowledge Bridges

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Abstract: Five regional meetings promoted by UNESCO in 2009 addressed the growing need for transdisciplinary approaches, holistic vision, incorporation of non-formal knowledge and views, effective participation and bottom-up action for identification of water problems and solutions. There is, however, a general context of tension and competition between specializations within different disciplines, and without specialization it is difficult to obtain formal and academic recognition. This paper presents insights into new co-learning methodologies centred in the experience of participants, inspired by and adapting the pedagogic approach developed by Paulo Freire, to the context of water management educational needs. This innovative approach has been applied as part of the Erasmus Mundus Master in Ecohydrology. The courses utilized the network of the UNESCO Hydrology for the Environment, Life and Policy (HELP) Programme to access experts with practical and academic experience. Drawing on their experiences and those of their colleagues, guest presenters and course leaders, the participants reflected on their practical IWRM challenges and reconsidered their options from new perspectives. Participants were encouraged to think "outside the water box" and focus on the role of IWRM in delivering society's broader policy objectives.

Keywords: *IWRM, co-learning methodologies, Paulo Freire pedagogy, UNESCO HELP network*

This paper is a first attempt at discussing the adaptation of a very powerful pedagogic stream, developed in the 1970's for a specific social context by Paulo Freire, to the challenges of knowledge-building to solve the increasingly complex problems in water management. Departing from a set of practical experiments through three Masters courses, we reflect on the challenges and outcomes of this approach. The following text is an exploratory incursion, bridging the worlds of water management and alternative views of education and the learning process, aimed at guiding water management practice and, ultimately, influencing policy change.

Introduction

The growing global water challenges are well documented (e.g., FAO 2011; UNWWAP 2009). Demographics and increasing consumption resulting from rising per capita incomes are the most important drivers or pressure on water (UNWWAP 2009). According to the UN, population dynamics such as growth, gender and age distribution, and migration create pressures on freshwater resources through increased demand and pollution. Further, landscape changes associated with population dynamics, such as migration and urbanization, can create additional pressures on local water resources and increase the need for water services (UNWWAP 2009). The anticipated impacts of climate change pose additional stress on food production systems already under pressure to satisfy the food needs of a rapidly growing and progressively wealthier world (FAO 2011). As agriculture develops and land and water use intensifies, the impact of agriculture on natural ecosystems becomes even more apparent. This impact damages the integrity of those ecosystems, undermining the food-producing systems that they support. According to the FAO (2011), effective adaptation to the impacts of climate change on water and agriculture will require a sound understanding

and integration of agronomic science with water management and hydrology, together with due regard for the resulting environmental interactions and trade-offs.

As pressure on the world's water resources has increase, it has translated into new and increasingly interconnected challenges. In response, water management has also changed over time with the introduction of new disciplines, new techniques, new language, and new thinking. Ecology, economics, and other social sciences have all progressively added to the historic hydrology and engineering base. The evolution and verification of new problems led to the need to adopt "imported" terms from other sciences (Neto 2010). This often led to the use of concepts that were originally defined for a determined purpose in a specific disciplinary context, being commonly used with diverse scope in other disciplinary areas. According to Neto (2010) "this gave rise to a certain conceptual confusion and the construction of a mixed terminology that was not always duly referenced. For example, the concern to bring the efficiency angle into the management of water resources so as to contemplate economic costs led to various terms originating from economics being added to the "hydrology" vocabulary. An illustration of this is the generally unsuitable and out of context application of the term "supply" and "demand" of water or the "water market," restricting the assertion to a service provision and interpreting water as a mere "commodity" subject to "natural monopoly." More recently, sociology, anthropology, and social psychology have also become part of solution to the challenges of water management. This has required re-thinking of some of the previously integrated terms and encouraged a more rigorous definition of the concepts used by different specialists (Neto 2010).

There has been a shift from seeking solutions within individual scientific disciplines to multidisciplinarity, interdisciplinary solutions and, more recently and increasingly, to transdisciplinary thinking and approaches – to seeking solutions in the interstitial spaces between scientific disciplines. Bammer (2005) describes the important differences in these approaches. Multidisciplinarity does not require researchers to leave their disciplines. It tackles issues by getting researchers in a range of disciplines to use their traditional theories and methods to present an understanding and then attempts to integrate these different understandings. In an interdisciplinary approach, researchers from small clusters of neighboring disciplines, such as physics, mathematics, and chemistry, or sociology and anthropology, look beyond their own discipline and work together to find areas of overlap likely to yield new understanding. A transdisciplinary approach aims to develop a new common conceptual framework that provides a new level of coherence for the different disciplines. According to Bammer (2005), "researchers must collaborate and integrate across traditional boundaries. They must bring together academic disciplines, and become more involved in the implementation of research in policy, product, and action."

There has also been a shift towards globalization of both problems and solutions. As problems become increasingly connected, they are also increasingly globalized. Recognition of this globalization of water problems has triggered awareness of the opportunity to draw ideas and possible solutions from a world of practical experiences in both similar and different contexts. "Researchers, funders, and research end-users are increasingly appreciating that new research skills must be developed if human societies are to be more effective in tackling the complex problems that confront us and in sustaining the sort of world we wish to live in" (Bammer 2005).

Recent experiences have increased awareness of the risks and consequences of water use decisions. Communities now expect developments to not only have acceptable environmental impacts but also deliver social and economic benefits. Furthermore, non-government organizations and individuals are better trained, connected and equipped to monitor decisions. Together, these trends are increasing pressure on decision-makers. Dealing with complexity and uncertainty emerges as a shared need and responsibility for government, developers, and the community so that good decisions can continue to be made (Camkin et al. 2008). In response to this pressure, there is rapid growth in the development of on-line

technology that utilizes new approaches to learning and supports communities of practice in the resolution of complex problems (Camkin et al. 2008).

Five regional meetings promoted by UNESCO in 2009 (North-America, Europe, Asia, Australia, Africa) addressed the growing need for transdisciplinary approaches, holistic vision, incorporation of non-formal knowledge and views, effective participation and bottom-up action for identification of problems and solutions in water education. There is, however, a general context of tension and competition between specializations within different disciplines, and without specialization it is difficult to obtain formal and academic recognition, either at undergraduate, masters, or Ph.D. level. The 2010 Capacity Building Workshop on Water Education in Paris identified the need to build tertiary or vocational levels that include participants with different backgrounds in order to facilitate cooperation and exchange of views. The integrated approach should enable communication between specialists addressing specific problems and other experts and practitioners, providing new skills and knowledge competences – a new "water practitioner" profile.

A key question is whether any ongoing tension between the need for transdisciplinary thinking and the disciplinary focus of traditional science, and the inclusion of non-scientific knowledge, is being sufficiently addressed to create the freedom and flexibility needed to tackle the increasingly interrelated and complex water challenges the world is facing. The UNESCO-IHP Hydrology for the Environment, Life and Policy (HELP) Programme, including its network of 91 river basins in 67 countries and more than 2,000 individual lawyers and policy makers, industry and community stakeholders, together with scientists of many different disciplines, provides an outstanding source of experiences, ideas, and potential solutions to water challenges. The UNESCO-IHP Ecohydrology Programme also includes a suite of demonstration sites where sustainable, innovative, and transdisciplinary water management practices based on ecohydrology principles are being implemented, providing yet another important source.

But what more needs to be done? The remainder of this paper presents insights into experiences of new co-learning methodologies being applied as part of the Erasmus Mundus Master Course (EMMC) in Ecohydrology, in collaboration with the UNESCO International Centre for Coastal Ecohydrology (UNESCO-ICCE) and the HELP and Ecohydrology networks. We describe the conceptual framework and our methodological approach, feedback from the courses, what we learned as course coordinators and some suggestions for the future of HELP and the Ecohydrology Demonstration Sites Programmes.

Conceptual Framework for a New Learning Methodology – a First Approach

An interdisciplinary approach to research is becoming essential for many reasons. As a foundation, we strongly agree with Siew and Döll (2012) who stress that "due to the interconnectedness of a multitude of scientific and social issues in human-environment systems, sustainable goals can neither be achieved by single scientific disciplines nor single groups of societal actors. Scientists from a variety of disciplines need to work in an interdisciplinary manner with a number of practitioners from problem-relevant sectors to seek collaboratively knowledge-based solutions, using new integrative approaches and methods." The core of transdiciplinary research is joint generation and integration of scientific and stakeholder knowledge (Jahn 2008), including recognition of the important role of non-scientific knowledge (Mobjörk 2010). By addressing real-world problems, transdisciplinary research goes beyond merely improving the implementation of scientific knowledge in practice (Siew and Döll 2012). The participatory transdisciplinary research process offers an opportunity for social learning towards sustainability (Luks and Siebenhüner 2007), helping to bridge the gap between the demand for knowledge and knowledge production (Cronin 2008).

The methodology used in these courses aims to apply transdisciplinary research approaches in a tertiary education context. It seeks to help bring out both the scientific and non-scientific knowledge held by course participants, lecturers and coordinators, and to apply that knowledge to real problems drawn from the experiences of the participants. From the outset, this approach was developed consistent with the main principles

and HELP philosophy – to include scientific and academic knowledge in useful usage by society, and also to improve the dialogue between scientific and non-scientific knowledge and practice. The methodology is fundamentally inspired in the work and pedagogic philosophy of Paulo Freire.

In Pedagogy of the Oppressed (Freire 1972), Freire provides a rationale for a pedagogy where he introduces the notion of banking education. Highlighting the contrasts between education forms that treat people as objects rather than subjects, he explores education as cultural action. The participant focus is a premise for a deeper understanding and involvement in the learning process. This requires also a strong capability of understanding (from the facilitators or mediators) and evaluating good practices and effectiveness of results towards some aimed principles (in this case IWRM goals and principles). The previous experience of the participants and the facilitators are, jointly, determinants of the success of the co-learning process.

Several aspects of Paulo Freire's work were particularly influential. Freire states that dialogue involves respect and that it should not involve one person acting on another, but rather people working with each other. However, he was also concerned with praxis - action that is informed (and linked to certain values). To Freire, dialogue is not just about deepening understanding - it is also about making a difference in the world. Dialogue in itself is a cooperative activity involving respect. The process is important and can be seen as enhancing community and building social capital and to leading us to act in ways that make for justice and human flourishing (Smith 1997, 2002). An important element for this process is the concept of "containerization," introduced by Freire, which means "developing consciousness that is understood to have the power to transform reality" (Taylor 1993: 52).

Situating educational activity in the lived experience of participants and its impact on informal educators was inviting. Freire's metaphors drawn from Christian sources, including the way in which the divide between teachers and learners can be transcended, also seemed particularly relevant. It was this path we chose to start building our contribution for a new learning process towards better water management practices, based in an integrative and transdisciplinary vision.

Water Education in the Erasmus Mundus Master Course (EMMC) in Ecohydrology

The EMMC in Ecohydrology is delivered through a consortium of the UNESCO Institute for Water Education (Netherlands), University of Lodz (Poland), Christian Albrecht University of Kiel (Germany), National University of La Plata (Argentina) and University of Algarve (Portugal). Several other research institutions and UNESCO Centres from Europe, Latin America, Asia, and Australia are associated with the course, contributing with advanced study courses and promoting student exchange. The EMMC is delivered over 18 months through four modules (thematic areas):

1. Understanding function, processes and threats to aquatic ecosystems;
2. Toolbox for applying Ecohydrology: environmental impact modelling;
3. Development of personal skills and research project implementation; and
4. Integration and specialization in management or engineering of aquatic ecosystems.

The authors of this paper were invited to develop new short courses as part of the EMMC curricula to be delivered at the University of Algarve in Faro, Portugal. Three courses were subsequently developed and delivered: Global Water Issues and Integrated Water Resource Management (IWRM) in December 2010 and January 2012; and Global Ecohydrology in Action in August 2011.

Global Water Issues and IWRM Short Courses

The first Global Water Issues and IWRM intensive short course was delivered over six days at the beginning of Semester 1 of the EMMC in Ecohydrology in December 2010 as an elective subject within Module 2: Toolbox for Applying Ecohydrology. There were 11 student participants from 11 different countries: Bangladesh, Bosnia, China, Ethiopia, Germany, India, Poland, Portugal, Tanzania, Turkey, and USA. The second Global

Water Issues and IWRM intensive short course was delivered over three days during Semester 1 of the EMMC in Ecohydrology in January 2012. There were 12 student participants from 11 different countries: Bangladesh, Chile, India, Indonesia, Italy, Malaysia, Poland, Portugal, Slovenia, Spain, Trinidad, and Tobago. In both courses, participants had a range of experience and a variety of backgrounds, including hydrology, geography, biology, ecology, fisheries science, environmental science, aquaculture, meteorology, and oceanography. They were introduced, through presentations and discussions with the course coordinators, to the range of current global water issues, the history and intent of key international agreements relating to water and the core principles of IWRM. In recognition that each of the participants already had important skills and experience, and that collectively the breadth of backgrounds and nationalities brought a wealth of learning opportunity, the participants were engaged in a co-learning dialogue with the course coordinators and their colleagues over the duration of the course. Through semi-structured exercises, including IWRM role-playing, participants expressed their own experiences and accessed those of their colleagues and coordinators. They were encouraged to continually think "outside the water box" and to focus on the role of IWRM in delivering a broader set of policy objectives. Participants were asked to reflect on the practical IWRM challenges they have been involved with and to considered their options from a range of new perspectives. At the end of the course, each participant give a brief "IWRM in Practice" presentation and submitted a final "Implementing IWRM in Practice" essay on a chosen experience, demonstrating how they might do things differently taking into account what they had learned through the course.

Global Ecohydrology in Action Short Course

The Global Ecohydrology in Action short course was delivered over three days at the end of Semester 2 of the EMMC in Ecohydrology in August 2011 as a core subject within the EMMC Summer School. It was designed to help balance the theoretical components of the EMMC with access to real life experiences. There were nine student participants from eight different countries: Bangladesh, China, Ethiopia, India, Kazakhstan, Poland, Tanzania, and Uganda. Participants were introduced to several practical examples of Ecohydrology in Action, drawn primarily from the UNESCO HELP and Ecohydrology Demonstration Site Programmes. On the first day, the UNESCO Global Coordinator for HELP and Ecohydrology Programmes gave an online welcome to the participants and each day they received online presentations from leading scientists, policy-makers, industry or community stakeholders involved with a HELP Basin or Ecohydrology Demonstration Site. From their offices or homes in New Zealand, Malaysia, Philippines, and Belgium, the guest presenters gave an overview of the HELP Basin or Demonstration Site and described the practical role that Ecohydrology is playing in management. Presenters were encouraged to add a personal touch through their own experiences and views. Participants and presenters were in visual and audio contact and the students had opportunities to ask questions or seek clarification during the presentations, and to discuss issues directly with the presenters during the online tutorial session that followed. Reflecting on what they had heard, participants were asked to identify the challenges faced, the management objectives, the ways in which Ecohydrology was contributing to meeting the management objectives, and to share their thoughts on whether the use of Ecohydrology principles has made a substantial difference. On the final day, each participant gave a brief presentation describing what they had learned about Ecohydrology from the Ecohydrology in Action examples and the EMMC.

At the completion of all three courses, participants were asked to provide feedback to the EMMC course convenors. To record their thoughts, at the end of the Global Ecohydrology in Action course, participants interviewed each other on video, spontaneously, and at their own initiative. These video recordings demonstrate that participants appreciated the course methodology. The participants obviously connected with the guest presenters and were able to recognize the relationship between the practical challenges being faced in the HELP Basins and Ecohydrology

Demonstration Sites, and the theory they had learned during other EMMC subjects.

The EMMC Coordinator summarized feedback from participants of these short courses: "The courses were very interesting. They covered a broad range of issues dealing with water resources and participants realized the crucial importance of considering the human dimensions in the management of water resources. They realized that without engaging society, both from the perspective of driver for the changes but also as receiver of the changes, it is not possible to find and establish sustainable solutions for water resources globally. The methodology of promoting dialogue with stakeholders and society that was taught was considered very useful by participants and it provided good results in enabling profitable dialogue with all the actors involved in the complex management of water resources" (L. Chicharo, pers. comm. 25 August 2011).

Conclusions

In these three courses we attempted to develop a new co-learning methodology, aiming at a transdisciplinary approach, which is built from the different background of each student, their own experience and expertise, and their expectations. Through the presenters and coordinators, participants not only benefited from new information and experiences but accessed personal professional networks that are based less on any disciplinary framework and more on a shared vision for IWRM. The participants were invited by several of the guest presenters to contribute their experiences and ideas towards solving existing challenges within the HELP Basins and Ecohydrology Demonstration Sites, further representing a fundamental shift from accessing a professional network and knowledge to becoming part of the network and knowledge base itself.

Critical to this methodology was also the commitment of individuals within the HELP network. The clearly evident emotional involvement and generosity of the guest presenters - they gave more than just their abundant knowledge - was a catalytic factor that helped participants make the connection between the individual subjects they had studied through the EMMC and the real problems they will have to solve in practice. This commitment and generosity, delivered in relation to real problems through subjects that consolidate the learning from the more technical subjects in the EMMC, was a powerful combination.

Besides different disciplinary backgrounds and countries, there were also very different socio-political contexts represented by participants from developing and developed countries. Actively encouraging the participants to put their stories on the table enabled all participants to view water problems from the widest range of perspectives, providing a significant learning opportunity.

The experiences of the EMMC Global Water Issues and IWRM, and Global Ecohydrology in Action short courses suggest that a substantial opportunity exists for the HELP community to actively and cost effectively contribute to meeting the needs identified at the 2010 Capacity Building Workshop on Water Education in Paris: tertiary and vocational level courses that include participants with different backgrounds in order to facilitate cooperation and exchange of views. Through courses such as these, the HELP community can support both immediate and longer-term communication between specialists addressing specific problems, other experts, practitioners, and emerging water professionals, providing new skills and knowledge competencies that help to develop a new "water practitioner" profile.

As ever, there is a need for both specialists and generalists to effectively address complex challenges. In addition, however, there is also the need for some specialists to broaden their knowledge beyond their basic training and explore the epistemological frontiers with other disciplinary areas. Here we call this higher level of expertise - of being able to "read" among different disciplines - "facilitators" (or "mediators"). This skill typically requires long experience and broad knowledge on the field, gained through different disciplinary exploration and experience. The methodology requires that these "facilitators" have that breadth of understanding of water issues and, most importantly, the ability to connect issues and concepts. It also requires acceptance that these knowledge "mediators" are part of the learning process, as co-learners. The ability to adapt and reshape the contents according with

the local needs of the community of participants is, therefore, essential to the success of this methodology. On the other hand, deeper and more specific disciplinary knowledge, where required, is also contributed through the use of extensive international networks, in this case primarily the UNESCO-IHP HELP Programme.

The methodological approach applied in these courses aims to support the development of new knowledge and skills that appear to be necessary to meet the increasingly complex water-related challenges the world is facing. This new knowledge and skills are complementary to deep disciplinary knowledge and there is no current risk of developing incompetence in disciplinary terms as the scientific process and educational systems remain strongly weighted towards disciplinary development. What is needed is greater capability for transdisciplinary thinking – for disciplinary specialists to work together to find the solutions in the interstitial spaces between individual disciplines, and to explore and develop epistemological bridges. This is the process we seek now, of moving from knowledge to wisdom in water management.

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References

Bammer, G. 2005. Integration and Implementation Sciences: building a new specialization. *Ecology and Society* 10(2): 6.

Camkin, J.K., K.L. Bristow, C. Petheram, Z. Paydar, F.J. Cook, and J. Story. 2008. Designs for the future: The role of sustainable irrigation in northern Australia. In Villacampa Estve, Y., C.A. Brebbia, and D. Prats Rico (Eds.) *Sustainable Irrigation: Management Technologies and Policies II*. WIT Press. 293-302.

Cronin, K. 2008. Transdisciplinary research (TDR) and sustainability. *Overview report prepared for the Ministry of Research, Science and Technology (MoRST)*, New Zealand. Available at: http://learningforsustainability.net/pubs/Transdisciplinary_Research_and_Sustainability.pdf.

Food and Agricultural Organisation (FAO). 2011. Climate change, water and food security. *FAO Water Report 36*. (Contributors) H. Turral, J. Burke, and J-M. Faurès.

Freire, P. 1972. *Pedagogy of the Oppressed*. London, UK. Harmondsworth: Penguin Books.

Jahn, T. 2008. Transdisciplinarity in research practice. In Bergmann, M. and E. Schramm (Eds.) *Transdiscplinary Research: Understanding and Assessing Integrative Research Processes*. Frankfurt/New York: Campus, 21-37.

Luks, F. and B. Siebenhüner. 2007. Transdisciplinarity for social learning? The contribution of the German socio-ecological research initiative to sustainability governance. *Ecological Economics* 63: 418-426.

Mobjörk, M. 2010. Consulting versus participatory transdisciplinarity: a refined classification of transdisciplinary research. *Futures* 42: 866-873.

Neto, S. 2010. *Water, Territory and Planning. Contemporary Challenges: towards a Territorial Integration of Water Management.* Ph.D. Thesis. September 2010.

Siew, T. and P. Döll. 2012. Transdisciplinary research for supporting the integration of ecosystem services into land and water management in the Tarim River Basin, Xinjiang, China. *Journal of Arid Land* 4(2): 196-210.

Smith, M.K. (1997, 2002). Paulo Freire and Informal Education', *The Encyclopaedia of Informal Education*. Available at: http://www.infed.org/thinkers/et-freir.htm.

Taylor, P. 1993. *The Texts of Paulo Freire*. Buckingham: Open University Press.

UNWWAP. 2009. The United Nations World Water Development Report 3: *Water in a Changing World*. Paris: UNESCO and London: Earthscan.

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