Universities Council on Water Resources
Journal of Contemporary Water Research & Education
Issue 150, Pages 6-17, March 2013

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

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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).

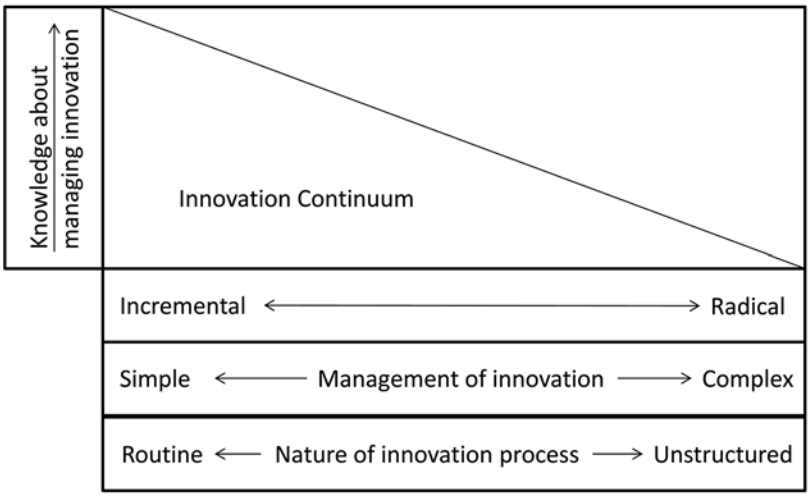

Figure 1. The innovation continuum (adapted from Tidd and Bessant 2004).

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

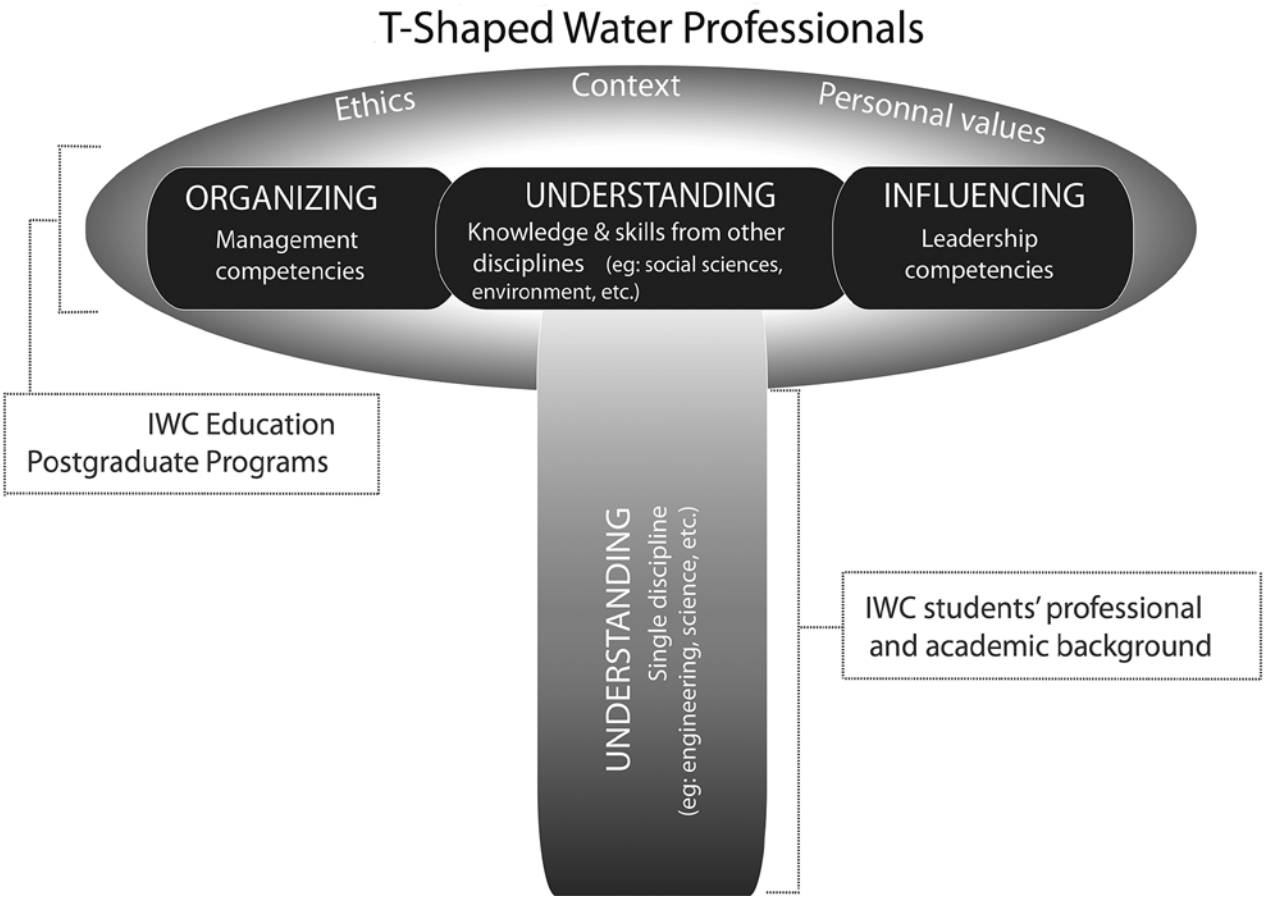

Figure 2. Conceptual model of a T-shaped water professional (used with permission from the International WaterCentre).

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.

Acknowledgements

This material is based upon work undertaken at the International WaterCentre supported by Griffith University, Monash University, the University of Queensland and the University of Western Australia.

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