

Cogitations on the Education of Water Resources Managers

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Contemporary education, ostensibly oriented towards producing a cadre of water managers that can deal with the emerging complexity of issues such as sustainable development and integrated water resources management, is failing to deliver the caliber of students that are needed by the public and private sectors. Existing programs have evolved to stress research on a wide variety of interdisciplinary subjects such as sustainable development and watershed management rather than the needs of management practice. The dilemma, of course, is that contemporary water resources management is an interdisciplinary venture, requiring a great deal of knowledge and expertise in many different fields. Yet, no single graduate program can deliver the requisite broad background without unduly diluting the curriculum. Some interdisciplinary programs further dissipate the knowledge base by promoting indoctrination into new and untested water management doctrines. Academia needs to rethink its approach and “return to the future” with more rigorous technical curricula that prepare its graduates for a professional career and that emphasize the basic principles, tools, and techniques that comprise the best management practices of the water resources profession.

Background

I was asked to reflect on the state of water resources education as a “user” of the “products” of the current educational system—i.e. the students that are being trained as water resources “managers.” This is a topic I’ve only vaguely thought about, mostly in sporadic fits of exasperation, so it’s not the scholarly view of an academician— which is probably why this perspective was solicited for this

special issue. Having been at the Corps’ Institute for Water Resources for the past thirty years, I’ve seen many changes in the technical demands and educational needs of water resources management, and have been involved both in training and updating the skills of our Corps workforce, as well as recruiting and mentoring many graduates of various water resources programs of the premier institutions around the U.S.

My initial reaction was, unequivocally, that the quality of both technical training (basic skills and tools) and scholarship (analytical reasoning) has demonstrably declined over the past few decades. All the national data on secondary and higher education for the past two decades support that observation, and there’s no need to dwell on it—it is self-evident, particularly in the fields most needed for water resources managers—engineering, math, and physics. The problems begin in primary and secondary schools, and the universities inherit a “defective” product. One could hope, in some naïve way, that while this decline may be true on average, that because of the nature of our work and the self-selection of students who are interested in water management and engineering, that our “profession” might still get its share of the top 25 percent of the students. Unfortunately, that is not the case, particularly in the public sector. The top ten percent seem to be heading elsewhere—into other professions that pay a lot more. Many in the top 25 percent are certainly not going into engineering or science. That still leaves a pool of 75 percent, and their training seems inadequate to do the job. The more difficult task is to ascertain why this is happening, and how this can be corrected.

Perhaps students are no longer motivated to become engineers, scientists, and practitioners. It doesn’t appear that the students are any less

intelligent than they were three decades ago. There seem to be two major, interacting reasons for the current situation: the students are not as motivated and diligent, or they have not been as well prepared for their vocations. A large part of the problem lies with the curriculum; the manner in which new interdisciplinary curricula have provided students “soft” choices. I have a feeling that not all is well in academia. Some top universities have no core curriculum requirements and do not grade students, using a pass-fail system. There are many other factors at work that have led us to our current unsatisfactory state, among which are curricula that promote interdisciplinary programs at the expense of rigorous analytical training.

What is Water Management?

What is a water manager and what kind of education and training is best suited for those responsibilities? These days, it's fashionable for just about everyone to consider themselves a water manager, including policy analysts, researchers, data collectors, professors and statisticians. In my world, a water manager is someone who *implements* policies, makes strategic planning choices, contributes to the management (plans, designs, operates, and maintains) of operating water infrastructure to *provide reliable services* in an effective and efficient manner. Management is performance-oriented problem-solving. Managers are not rewarded for writing elegant papers – they are rewarded for keeping their fingers in the dikes. Policy makers are not water managers – good managers routinely make imperfect policies work effectively. They are the *implementers who are accountable* for their decisions and actions, and focus on *outcomes* (reliable water supply, clean drinking water, reduced flood damages) rather than *outputs* (published papers, workshops, conference proceedings, data bases, plans, policies, regulations, models, criteria, standards).

This definition may not square with how academia views water management, but that's part of the problem of educating water managers – whose definition holds? My definition calls for a different sort of education than is currently offered by many, if not most graduate schools – one that stresses accepted best management practices,

best practicable technologies, and sound, conventionally accepted approaches. The problem is exacerbated because practicing professionals generally do not have the time or inclination, nor are they rewarded for, publishing papers on their experiences. There exists an imbalance then, in the literature that students are exposed to in any given field, with theories and conceptual models dominating case studies and expertise. So students are given a skewed, if not unrealistic, view of the state of practice through the literature to which they are exposed.

What I observe, then, is that we are getting students who “know” a little about such complex issues as sustainable development, integrated water resources management, global change and watershed management, but can't execute a fundamental analysis of flood frequency or life-cycle infrastructure costing or employ a hydraulic model or watershed model correctly. There are numerous “canned” models and algorithms for this – yet there is generally a fundamental failure to understand the basic mathematics, empirical physics, and rationale as to how these models are built and what their limitations are, under what circumstance they should be used, and what the next best alternative might be. This is a fundamental deficiency of technical expertise that cannot readily be compensated with subsequent work experience.

Interdisciplinary Education

Glassick (1993) discusses “scholarship” and how it has been transformed in American universities by citing excerpts and conclusions from a report of the Carnegie Foundation (1987) that dealt with a new vision of scholarship. The Carnegie report stated that scholarship was routinely defined as equivalent to research, in fact, research followed by publication in refereed journals in specialized disciplines – this is often the only yardstick used to measure scholarly productivity. Instead, the Carnegie report expanded the definition of scholarship to include:

- a. the scholarship of *discovery* (research that contributes to the stock of knowledge);
- b. the scholarship of *integration* (synthesizing, giving meaning to isolated facts, making

connections across disciplines);

- c. the scholarship of *application* (applying knowledge responsibly to consequential problems); and
- d. the scholarship of *teaching* (creating a common ground of intellectual commitment, transmitting knowledge and experience, transforming and extending it).

“These four types of intellectual activity must be acceptable, be recognized, be rewarded, and be respected throughout the academy” (Glassick 1993). Easier said than done – there are structural institutional and professional cultural factors and disincentives in academia, as there are in governmental institutions, which make this simple truism difficult to implement (see Russell in this issue).

Is it appropriate to impose a research-oriented curriculum for students who want to pursue a technical professional degree that has stringent licensing and certification requirements? Academia needs to find a way to allow students who choose water resources management as their *profession* to follow one or two of the four tracks (application and/or integration), by devising curricula that address those needs and rewarding professors for selecting one of those tracks. There should be a distinct difference between a Master of Science in Engineering, which requires an 18 month program and a research thesis, versus a Master of Engineering, which is built on a 12 month rigorous analytical curriculum that focuses on professionally required knowledge, directed towards real-world problem-solving. We want the M.S. candidate to consider working at the Corps’ Hydrologic Engineering Center, and the Corps would be well-served in getting the MEng candidate to work at any one of their District offices. Allen (1993) makes a key point that individual disciplinary research produces new knowledge for that discipline, whereas interdisciplinary projects (research, studies, programs, etc.), provide a synthesis of knowledge that better address complex real world problems. True, but here’s where I depart from the academician’s concept. The difference here is critical – between *multi-disciplinary* problem-solving and synthesis and *inter-disciplinary* education and training. *Multi-*

disciplinary teams are essential to the basic nature of most water resources management problems—whether it’s agricultural irrigation planning, watershed management, or reservoir allocation or regulation studies. But multi-disciplinary teams are comprised of individuals with specialized disciplines – they are experts in their individual fields – whether hydrology, economics, or ecology. In my experience, I’ve dealt with and led both types of teams—the *multi-disciplinary* team wins hands down. Naturally, as the disciplinary “experts” (hydrologists, economists, environmental engineers, etc.) mature, they acquire a fair degree of on the job practical interdisciplinary training. Most team leaders become the interdisciplinary synthesizers, by virtue of their experience in the field of water resources management.

Obviously, it is important for students to learn the underlying theory of conventional engineering practice, as well as the best management practices of the profession of water resources management. The principles and theories are the foundations of the practices – the analytical techniques, models, standards, procedures and regulations. Water resources *management* is inherently a practical discipline, and the curriculum needs to reflect that reality. Too many water related curricula have forgotten that basic requirement.

A prime example is the general failure of many academic water departments to pay much attention to the Water Resources Council’s ‘Principles and Standards/Guidelines’ (WRC P&S 1973, WRC P&G 1983). For three decades, federal water planners used these as part of the best management practices for water resources planning. Contemporary academic curricula generally fail to explain the legally-required and theoretically-sound conceptual and technical basis of agency decisions based on the Principles and Guidelines. Here is a body of work that, for water resources planners, is equivalent to the Clean Water Act, embodying as it does the best principles, theories, and practices of over 50 years of water management, including those of Otto Eckstein (1958), Gilbert White (1969) and the Harvard Water Program (Maass 1962). Hardly any mention of it is made in graduate courses. Ignoring the P&S is equivalent to teaching catechism without referring to the Bible, or teaching hydrology without covering the accumulation of

all the empirical methods used for flood frequency analysis, and moving directly to fractal theory, or economists ignoring benefit cost theory and applications, focusing only on microeconomic theory. Unfortunately, there is no effort underway to bring together the rapidly evolving new ideas, experience, and literature into a new coherent paradigm for water resources management, as was accomplished with the path-breaking work of the Harvard Water Program (Maass 1962).

Analysis vs. Advocacy

Beder's (1999) views reflect those of numerous contemporary scholars that I've encountered at many conferences, views that exemplify the dilemma, difficulties, and dissipation of a modern water resources engineering education, adding yet another digression from the fundamentals of sound technical training by preaching a form of "advocacy engineering":

Engineering appears to be at a turning point. It is evolving from an occupation that provides employers and clients with competent technical advice to a profession that serves the community in a socially responsible manner. Traditional engineering education caters to the former ideal whilst increasingly engineers themselves and their professional societies aspire to the latter.

A new educational approach is needed to meet these changing requirements. It is no longer sufficient, nor even practical, to attempt to cram students full of technical knowledge in the hope that it will enable them to do whatever engineering task is required of them throughout their careers.

A broader more general approach is required...

This school of thought seems to be saying that technical virtuosity is necessary but not sufficient to be a good water resources manager, that technical virtuosity in the management curriculum comes too much at the expense of philosophies that are intended to broaden the students' perspective to be "more socially responsible." Beder's views are part of a "politically correct" academic attitude that forces engineers to advocate "...appropriate technologies that minimize environmental and social consequences." Beder's views suggest that engineers do not behave in a socially responsible manner and are reluctant or incapable of designing sustainable technologies. There are many scholars

like Beder, whose approach is to advocate, through the curriculum, solutions that can be impractical and untested, that are not cost-effective, reliable, or even feasible in many economic settings. Beder speaks as if *civil* engineers never had a code of ethics, and never understood their professional obligations towards civil society, and are unaware of the world around them. In fact engineers are among the very few professions that do have a long-standing code of ethics that emphasizes their key role in providing solutions that society demands. They respond to the demands and wishes of society – that is why they are "civil" engineers. Beder's philosophy is common among faculty in disciplines involved in natural and water resources management, and this is the sort of thinking that subverts a sound professional education.

Engineering as the Core of Water Management

Water resources management evolved from engineering curricula, which are among the most rigorous in academia. Engineering curricula have undergone some changes, but according to Russell and Stouffer (2005), now require 75 percent of credits to be in engineering and math and science subjects, down from about 85 percent in the 1920's. Perhaps one of the key reasons that engineering has become less popular over time, is that it is still among the most rigorous of college curricula, and does focus on professional and practical skills. Engineers recognize, through their professional code of ethics and licensing requirements, that they have a civic duty, akin to the medical profession, to "do no harm." Nonetheless, the authors conclude that "... even as the complexity of the modern engineering project continues to mount . . . students are, on average taking 18 fewer technical credits in the curriculum today than in the 1920's." In addition, students are taking more electives in their area of specialization, further diffusing the core curriculum. According to Bordogna (1998) and Cohon (2000), a well-rounded fundamental education is no longer possible, and runs counter to the need for what many leading educators are calling for – "master integrators" and "master builders" – as the new attitude for the engineering profession. Russell and Stouffer (2005) conclude

"...without a refocusing of the current education,

or an increase in the number of credits, civil engineering may continue to splinter into multiple sub-disciplines that will become ever more fractured and marginalized. This is already happening to engineering as a whole.”

Modern water resources management requires an interdisciplinary background, but every profession needs to be grounded in some core technical curriculum. That is the dilemma of modern water resources education today – the field is so complex, that any curriculum that attempts to cover all the bases rapidly leads to a diffusion of knowledge and expertise. How does academia balance the need to provide the basis for a sound professional background, based in technical expertise, while opening the student to the complexity of modern water management? The answer is fairly straightforward – go back to basics. The basic undergraduate degrees need to be much more rigorous than they are now, and the graduate degrees ought to be used to both specialize and integrate.

Some universities have dual-track systems at the universities – one for research and academia, the other for a professional career. An equivalent system was in place, *de facto*, through the two-tier college system we had – the liberal arts colleges, and the Land Grant colleges. For 90 percent of the routine tasks associated with the basic issues of water resources management in a typical agency, the hydrologic, hydraulic, and water resources engineers with bachelors degrees from the historical land grant colleges outperformed those with comparable degrees from the liberal arts colleges. They were simply better prepared in the fundamentals of the profession. The routine work of an agency, utility, or a private engineering firm does not require research-oriented scholars, as there are other mechanisms for addressing those issues. Each agency has its research arms, and it is their responsibility to keep abreast of the latest developments and intersect with academia to develop and peer-review the latest analytical methods.

The educational establishment seems to be suggesting that because of the rapid changes in society, the engineering and technical curricula should be adjusting and accommodating a more diverse view of the subject matter. This is precisely the opposite of what I think is needed, and is a view

supported by many academicians. The experts (Smerdon 2000, Beder 1999, Bordogona 1998, Duderstadt 2008, National Research Council 2005) say that there are many trends and changes that will affect engineering and hence the educational processes need to change if the U.S. is to stay competitive:

- New technologies are emerging at a much quicker pace,
- Companies narrow their focus to the core business,
- Design activity involves a broader range of disciplines,
- Globalization of engineering practice and increased competition,
- Concept-to-product time shortened,
- Expanded information technology,
- Knowledge management is a greater factor in engineering practice,
- Engineers change jobs more frequently and companies change more quickly, and
- More engineers work in small companies.

Given all these rapid changes, the National Academy of Engineering lamented the excessive specialization within graduate programs, and stated that “What is needed is not additional specialization. We need a graduate system that is well tuned to the central feature of contemporary life: continuous change. Uniformly, they concluded that continuing education was essential to stay competitive within the profession and to keep up with the rapidity of changes in the profession.

Professors of tomorrow must look at the market and determine what the customers want. The immediate relevancy of the coursework to the persons’ professional goals will become increasingly important. The professor of tomorrow must focus on student needs and not his/her personal desires (Smerdon 2000).

The reality is that civil engineering is at the core of water resources management and this interdisciplinary field has evolved over the past 50 years to reflect the prescriptions of the educators, such as Smerdon. But my sense is that the field has become too diffuse to effectively teach as a

profession, and one can only become an “expert” through a combination of a rigorous degree and practical experience, complemented by a life-long dedication to updated training.

Conclusions

1. Engineering is, and should be at, the core of the water management profession – all other disciplines (economics, social science, ecology) are complementary to the principal focus of water management.
2. Educators should consider revising engineering education, so that it is similar to the MBA degree requirements. This will further professionalize the water resources management degree. A bachelors degree ought to be followed by several years of practical experience before moving onto a graduate masters degree level.
3. The masters degrees should be split into two paths – research (18-months with a thesis) and professional practice (12 months).
4. Academic, research-oriented curricula ought to continue focusing on theory and advanced analytical methods, with cross-overs for the professional tracks.
5. Interdisciplinary programs are valuable, but should be based on a rigorous core curriculum.

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