The university sector and the water industry – are we integrating the two for effective education?

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Structured abstract

BACKGROUND
As noted in a variety of professional reports, the water industry is currently experiencing a skills shortage due to many career engineers either leaving the profession or reaching retirement age. The question that remains is: *What is being done at the tertiary level to fill this shortage?* According to the National Committee on Water Engineering (2010), "The education of water engineers should be viewed as a process that initiates undergraduates into water engineering and then maintains and nurtures their skills and professionalism throughout the remainder of their career." That is, tertiary study should be seen as the start of an engineer's learning journey, with industry experience continuing the education process all the way to retirement.

PURPOSE
To see how much emphasis universities place on water engineering education, an examination was performed on the weighting of courses offered in the area of water engineering within bachelor of civil engineering programs currently offered at tertiary institutions across Australia.

DESIGN/METHOD
The courses counted under the heading of 'water engineering' included the well-recognised ones such as fluid mechanics, hydrology and hydraulics, as well as water and wastewater engineering. This did not include courses that may have incorporated an imbedded design component or special topic, due to difficulty in determining the component weighting. It is important to note that while Engineers Australia does not specify exact course content and structure, it does provide general guidelines, so it is up to the individual institutions to determine exactly what is taught.

RESULTS
From examining 27 undergraduate programs offered by Australian universities, it is clear they all offer the basic fluid mechanics and hydrology-based courses. Their exact content can vary, but they do aim to address the fundamental knowledge requirements essential to water engineering. Further analysis reveals a significant issue, which is that few, if any, other water or wastewater engineering courses are considered a core requirement.

CONCLUSIONS
A study of core courses currently undertaken by undergraduate engineering students across Australia reveals they experience only a small degree of exposure to water engineering courses. Consequently, upon graduation, they may be unfamiliar with the profession, which could lead to a severe skills shortage in the near future.Therefore, changes to educational programs will need to be considered.

KEYWORDS
Water engineering education, program design

Introduction

Developing undergraduate degree training programs requires universities to be proactive in their decision-making processes and to engage with the relevant industries, accreditation bodies (internal and external) and skilled advisory bodies. As noted in a variety of industry reports, the professional water industry is currently experiencing a skills shortage due to many career engineers either leaving the profession or reaching retirement age. The question that remains for the university sector is: *What is being done at the tertiary level to fill this shortage?*

According the National Committee on Water Engineering (2010) (herein referred to as NCWE (2010)), *The education of water engineers should be viewed as a process which initiates undergraduates into water engineering and then maintains and nurtures their skills and professionalism throughout the remainder of their career.*

That is, tertiary studies should be seen as the start of an engineer's learning journey, with industry experience continuing the education process all the way to retirement. Accordingly, NCWE (2010) notes that the educational approach should achieve a number of broad objectives (see Table 1).

Table 1: NCWE (2010) Water Engineering requirements

1. The water engineer should have a sound understanding of the natural sciences that underpin water engineering. These include the sciences of fluid mechanics, hydrology (surface and subsurface), water chemistry and aquatic aspects of the biological sciences. This understanding must emphasise both process and mathematical description.
2. Building on the natural sciences is the need for adequate exposure to the social sciences. Economics, law, ethics, management, and the sociology of public and private policy formulation and decision-making present the social framework within which engineers operate, while communication skills provide the vehicle for exchange of ideas and solutions.
3. The water engineer should be skilled in the engineering sciences that underpin the practice of water engineering. Skills include the traditional fields of hydrology, hydraulics, water and wastewater treatment technology and water resource planning and management, and are evolving to include catchment management.
4. Water engineers work in a problem-oriented environment seeking to provide practical solutions. At times the challenges they face are without precedent or at the cutting edge of technology and practice. In response to such challenges they need to develop the art of problem-solving as well as holistic or systems-thinking skills. Such skills include the ability to systematically and critically analyse problems, to think laterally and independently, and to navigate through the social and technical complexities of modern water engineering infrastructure. Such skills are fundamental to design, and to project and resource management.
5. A sense of professionalism must be instilled. Engineers must understand their ethical obligations to society (both present and future), and to their clients. Within this framework they must practise in a competent and responsible manner. Moreover, they must recognise that their education never ceases - it is a lifelong experience requiring the ability to learn how to learn. They must undertake continuing educational activities throughout their professional lives.

Table 1 indicates that a large number of requirements need to be met during the educational process of a prospective water engineer's training, and it is clear that not all of these can be fully achieved within the university sector and within the timeframe of a typical four-year undergraduate degree. For example, Point 5 in Table 1 requires a lifelong learning approach. However, this is something that universities can instil in their students, and indeed, this is an expectation for a graduate engineer, and for many universities, as a graduate attribute.

In addition to the requirements presented in Table 1, it is essential that universities achieve program accreditation, which in itself requires satisfying internal and external authorities. In Australia, this is Engineers Australia, which has a stringent accreditation process requiring students to achieve a minimum standard of competencies that cover a broad range of skills and knowledge—not only technical (Engineers Australia, 2014b).

It also is evident to university staff that the student cohort is ever-evolving as new technologies and the industry's environment and expectations continue changing (Martin, 1997; Lemckert, 2003; Ludwiget al, 2003; Chansen, 2004 and Byars 2009). Thus, the water engineering education sector must adopt a flexible approach to their teaching strategies, seeking ways to encourage students to undertake a continuing career in the water industry. Additionally, the industry must find effective ways to recruit and sustain the career of emerging water engineering professionals. The following section, which focuses on civil engineering undergraduate programs, details the current state of play with water-oriented courses available within Australian university programs. It then proposes methods that have and could be used to better prepare students entering the water engineering workforce. It is well recognised that other forms of engineering also offer water training, with chemical and environmental disciplines having a high impact, and it is proposed that these also seek similar and/or additional methods.

Water component of Civil Engineering programs – undergraduate level

Civil engineering programs have traditionally been the major supplier of engineering professionals for the water engineering sector within Australia. These degrees are generally completed over four years and comprise both on-campus study (but some with distance mode delivery) and various components of industry placement and required professional engineer supervised experience (Patrick et al, 2008, Engineers Australia, 2014a). Today there is also a drive to promote 3+2 year programs, with at least two universities offering this option as their primary focus. It is also recognised that other programs of study (including environmental engineering) also supply qualified water engineering professionals.

All engineering degree programs are required to satisfy Engineers Australia accreditation guidelines (Engineers Australia, 2014a). This is necessary so that undergraduates, upon completion of their degree, can join Engineers Australia as a graduate engineer and begin their professional career.

To see how much emphasis Australian universities place on water engineering education within the standard four-year (full-time) civil engineering undergraduate degree programs, a quantitative examination of published programs of study was performed. The aim was to determine what proportion of core courses was dedicated to water engineering. For comparative purposes other streams were also examined.

The courses counted under the heading of 'water engineering' included well-recognised ones such as fluid mechanics, hydrology and hydraulics, as well as water and wastewater engineering. Due to difficulty in determining components within an obscurely-named or generically-titled course, we did not include courses that may have incorporated an embedded water engineering design component or special topics. Therefore, the result may be a slight underestimate. Additionally, elective courses were not considered as students may not have chosen this option. The percentage of the water courses within a program was

then determined from: Percentage of water courses = (weighted sum of water courses)/(weighted sum of all core courses)*100. Here the weighted sum is the relative weighting of a course per semester. For example, if all courses in a degree were of equal weighting, the total number of core courses was 30, and the number of water courses was three (eg Hydraulics, Fluid Mechanics and Water Engineering), then the percentage of water courses in the program = 3/30*100=10%.

It is important to note that, as Engineers Australia does not specify exact course content and structure (although they do give general guidelines), it is up to individual institutions to determine precisely what is taught. This approval should be the result of benchmarking, university and Engineers Australia requirements and industry reference groups.

Examination of 26 undergraduate programs offered by Australian universities established that they all offer the basic fluid mechanics and hydrology-based courses. Their exact content can vary, but they do aim to address the fundamental knowledge requirements essential for water engineering. This satisfies the first point presented in Table 1 and, one assumes, the general expectations for Engineers Australia for minimum water engineering technical content.

Further analysis reveals a significant issue – few, if any, other water or wastewater engineering courses are offered as a core requirement. This means that the knowledge and skills detailed Points 2 and 3 in Table 1 may receive very little coverage throughout a four-year degree. Therefore, further education is likely and probably essential (and is usually delivered through ad hoc activities or postgraduate programs). Across all of the undergraduate civil engineering programs offered, both Point 4 and Point 5 in Table 1 are sufficiently covered throughout the general coursework program, and therefore meet Engineers Australia requirements.

Figure 1 presents a summary of the weighting of dedicated water courses offered across each of the 26 civil engineering degrees under analysis. The average component of course work dedicated to water engineering is 10.4%, with a maximum of 16.7% and a minimum of 4.4%. This is a very low percentage when compared with other streams such as civil structural engineering (average = 20.3%, maximum = 33.3% and minimum = 5%) and mathematics (average = 11.4%, maximum = 17.4% and minimum = 6.3%). It is important to remember that these results are based on the selection of courses generally based upon their title and some consideration of content. Analysis of the data collected reveals there is no statistical significant relationship between the three streams mentioned streams, indicating that formal content guidelines are not in place for the delivery of technical matter. This is not surprising, as Engineers Australia does not generally enforce actual technical content, instead (expectedly so) focusing more on their required Level 1 competencies (Engineers Australia, 2014).

Students may enrol in elective water courses if they wish – resulting in some students undertaking a higher percentage. However, as they are so familiar with other streams of the course, water engineering options may appear difficult and daunting, and as a result are avoided. Therefore, techniques must be developed to get around this issue. This includes encouraging universities to offer more core courses in water engineering, such as water resource management or water systems modelling.

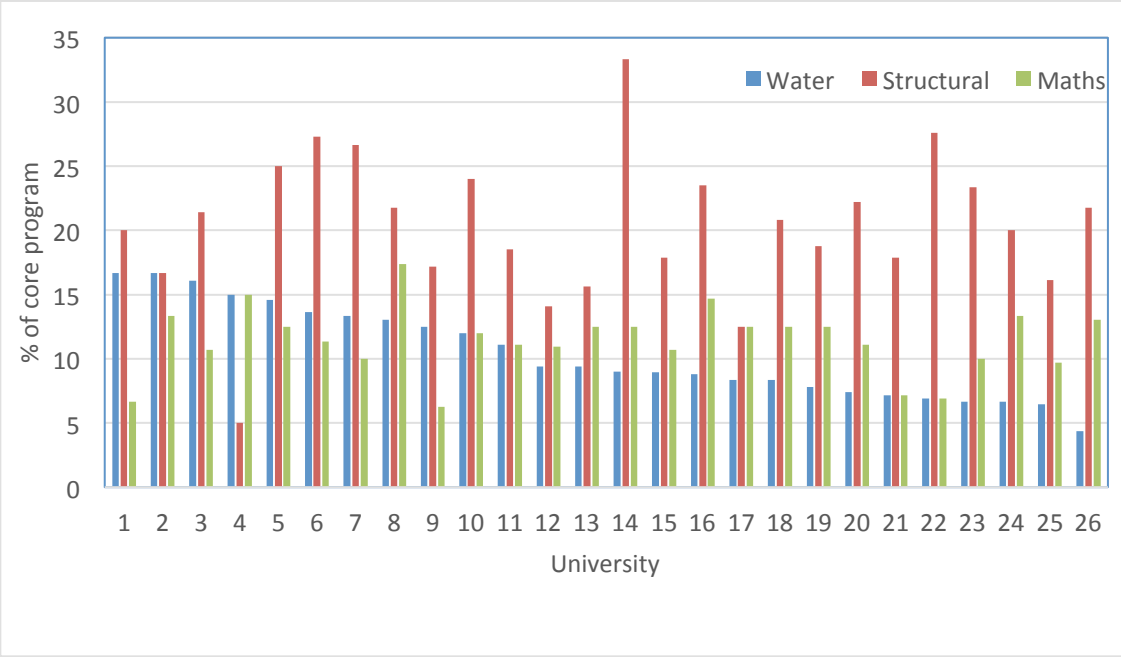

Figure 1: Percentage of core water, structural and mathematical engineering courses within Australian university Bachelor of Civil Engineering programs (in 2014)

How to encourage students into water engineering at the university – undergraduate level

AWA

The Australian Water Association offers many successful water education programs and methods designed to foster interest among primary and secondary students in water and the industry (AWA, 2011). Many programs are also aimed at the community and professional sectors, but very few courses are provided for the University sector.

A proposed strategy to encourage more water engineers would be to develop programs aimed at attracting prospective university students to undertake a career in water engineering. This would require significant research and planning, but possible mechanisms are:

- Offer students direct traineeships within the water sector;
- Offer students scholarships while they study;
- Supply academic staff with up-to-date resources on the state of employment within the water sector (for example, access to up-to-date Power Point slides);
- Encourage water professionals to engage more with the university sector by providing industry-funded secondments; and
- Set up chair(s) in water engineering education within the university sector, as opposed to water engineering research.

Presently, chair and secondment positions are aimed at developing research-led innovations in water engineering, and are primarily aimed at enhancing efficiencies. Unfortunately, no focus has been placed thus far on encouraging students to enter the water engineering sector. This could be remedied by instigating industry-supported university education. However, as there are no immediate profit/efficiency outcomes from a professional educational placement, a whole-of-sector supported approach will be required.

Industry Affiliates Program (IAP)

Within Griffith University, Queensland, Australia, students are required to undertake a semester of industry placement during their fourth year of study, where students work interactively with industry and academic staff on a focused and directed engineering project (Patrick et al, 2008). The IAP has proved highly successful, with many students continuing employment with their industry partner following completion of their degree. Therefore, to help students pursue water engineering careers, the more resources and personnel the water industry can contribute to such schemes, the better. Over the past two years, with factors such as the Global Financial Crisis (GFC) and placement of stronger scrutiny on government spending, it has become increasingly difficult to find industry partners willing to be part of the IAP, as it does require a substantial investment of their time and resources. Thus a concerted effort must be made to highlight the benefits of these programs to the water industry. Here it should be noted that this year the majority of IAP students are engaged in water-based projects, but there is still a long way to go.

Possible new initiative at Griffith University

A mechanism aimed at encouraging students into the water industry was recently proposed by staff from the Smart Water Research Centre (http://www.smartwaterresearchcentre.com/) hosted at Griffith University. The facility currently offers a number of water professional courses, but at this point in time, none is provided for university students.

The proposed scheme aims to offer students a range of professionally-focused courses whose completion accelerates their progress through their undergraduate degree. Currently, the Bachelor of Engineering in Civil Engineering degree at Griffith University requires students to complete four (4) elective courses. It is proposed that water-focused courses could be taken as electives by engineering students considering a career in the water sector.

The courses (which will all be fully accredited within the university, meeting strict degree requirements), will be taught by a range of water professionals and academic staff. This will help to address some of the requirements presented in Table 1, thus exposing students to modern real-world water research and management applications and making the student more industry-ready. This in turn will enhance their employability.

This initiative is still under development, with its effectiveness to be determined by future qualitative and quantitative examination of its outcomes.

Conclusions

From a study of core courses currently undertaken by undergraduate engineering students across Australia, it is evident they experience only a limited degree of exposure to water engineering courses. Consequently, they may be unfamiliar with the profession and relatively unskilled in this important area of civil engineering. This could therefore lead to a severe skills shortage in the near future. This situation warrants significant further investigation and analysis, including direct student, university and industry surveys to see if and how this situation could be altered to improve water engineering study exposure. Importantly, it is important to determine if the core material / learning outcomes expected for graduate water engineers are being delivered – especially as perceived by the graduate's employers. Additionally, further study is recommended within the international context as many engineering graduates now work in the international space.

Although there is a perceived lack of core undergraduate water engineering courses, institutions are actively making an effort to enhance water engineering education. This includes allowing students to undertake a variety of electives or by offering postgraduate programs where significant use is made of industry professionals and more emphasis is

placed on water industry-specific needs (satisfying Point 5 – lifelong learning – see Table 1). How progress is made from here is up for discussion, but it would certainly be desirable for the water industry to play a more active role within the university sector, with a particular emphasis on the educational component. A possible mechanism for this is the provision of financial support for on-campus professionals to serve as lecturers and mentors to students and staff.

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