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Role of case study research in training the renaissance water engineer

Amit P. Chanan†, Jaya Kandasamy‡ & Saravanamuth Vigneswaran‡

State Water Corporation, Sydney, Australia†
University of Technology Sydney, Broadway, Australia‡

ABSTRACT: Contemporary water management challenges around Australia highlight water engineers' inability to understand the community's needs. Developing new technologies is not enough. Implementation of these technologies can only take place if the engineers understand the motives and desires of people that are related to the new technology and the effects on the community as a whole. Renaissance water engineers who are able to go beyond their own technical specialty and understand the broader implications of the technological solutions they develop, are needed to solve Australia's water problems. Our ability to produce such engineers depends on our ability to first prepare renaissance engineering academics within our higher education institutions. It is, therefore, imperative to re-examine current practices in engineering PhDs. The engineering discipline is urged to embrace the case study research approach as a vital means of training renaissance water engineers.

Keywords: Case study research, renaissance engineer, sustainable water management

INTRODUCTION

It is now acknowledged that sustainable water management in the future will be significantly different from the traditional centralised water management paradigm that dominated the last 100 years. Meeting the demand for water by simply augmenting supply and removing the hazards of wastewater and storm water to prevent the spread of disease are no longer the main driving principles of urban water management [1].

The suitability of the traditional urban water supply, sanitation and drainage systems, each separately designed and operated is now commonly being questioned [2]. Over the last two decades, the concept of Integrated Water Cycle Management (IWCM) has attained widespread acceptance throughout the world [3]. IWCM treats storm water runoff and sewage as resources and cuts down on their wasteful pollutant loaded discharge into waterways [4]. IWCM is defined as a holistic multi-dimensional approach to managing urban water that ensures optimal use of all water resources, based on the fit for purpose concept [5]. IWCM calls for integrated management of water quality and quantity for all three arms of the urban water cycle, including potable water, wastewater and storm water to meet economic, social and environmental objectives [6].

In order to train water engineers capable of working with this holistic multi-dimensional approach, a new paradigm in engineering education is required. It is acknowledged that at the undergraduate coursework level, new subjects have had to be introduced by most academic institutions, to introduce sustainability to civil engineers. This article, however, puts forward a proposition that the PhD level in engineering is where this new paradigm must now be institutionalised, and interdisciplinary case study research will play an important role in its delivery.

OUR WATER PROBLEM

> *Australia's water and waste water systems were developed as one pass systems and this is the paradigm that has conditioned the approach and direction of most Australian water utilities. Against this background, efforts to promote Integrated Water Cycle Management (IWCM) have been reduced to peripheral status instead of being accepted and embraced as the primary basis for management of a scarce resource* [6].

The rather tepid implementation of IWCM in Australia has been well documented [2][4][7]. Despite opportunities for embracing IWCM, there has been limited progress in the achievement of such options. Policy stalemates on water recycling initiatives were a result of failure on the part of water managers to understand community values and gain support for IWCM [4].

Our current water scarcity problems have in fact developed because our management has failed to apply whole-of-system thinking to water supply, reuse, consumption and return of water to natural water bodies. Management of surface water and groundwater as independent entities, similarly management of urban storm water and sewage treatment, and effluent reuse as two unrelated units of the water cycle are example of this failed management model [8].

Despite a plethora of literature stressing the importance of IWCM, and advancements in engineering and science creating new enabling technologies for such management of the water cycle, difficulties in promoting implementation have remained. Limited application suggests that behavioural and institutional reasons may well come into play [7]. It is, therefore, important to acknowledge that sustainable urban water management in Australia is a multi-dimensional problem, of which technological innovation is only one of many important foci for research. Water engineers need to understand how engineering knowledge can be applied in the governing of the socio-technical system of water use [7].

Key processes and assumptions that underlie dominant modes of practice in the Australian water industry are part of the problem. It is because they have a tendency not to conceive of the water cycle as a whole, and to regard its components as disconnected functions vested in different agencies [9].

It can be argued that the Australian water problem is the water engineers' inability to see themselves as water service providers and not just sellers of *water* [10]. Tied within this description is the way water engineers view urban water users, where the traditional approach simply sees them as consumers with no involvement in the governing process. Water service provider philosophy, on the other hand, requires inclusion of appropriate stakeholders in the decision-making process. Stakeholders may range from departments within the water utility, to other government agencies, as well as community representatives. Appropriate stakeholder involvement can negate the current risk of disconnect between *what is required, what is planned, what the community consider appropriate and what actually happens* [10].

The above discussion emphasises the transforming nature of our water problem, from being a public health and flood prevention challenge of the 19th Century to a multi-dimensional challenge of water security for the 21st Century. In relation to the multi-disciplinarity, it has been observed that urban water management was becoming integrated with other professional areas like land use policy, urban landscape planning, urban development, building design and construction, economics, regulation and legislation, education and social acceptance, and community involvement [11].

From designing major infrastructure to achieve economies of scale and meet ever-increasing demand projections, water engineers now face a multi-dimensional problem. IWCM has elucidated that solving this multi-dimensional problem requires integrated demand and supply side solutions developed in consultation with stakeholders. We have all heard the old adage - *Engineers Solve Problems!* The challenge that the engineering profession now faces, is to have appropriately skilled water engineers to solve this problem.

OUR PROBLEM SOLVERS' PROBLEM

The profession of scientifically trained engineers came into existence in the 18th and 19th Centuries. It was in fact a product of the Enlightenment, which implied rearranging political and administrative structures in a rational way to abandon superstition and injustice. For the engineering profession, it resulted in the training of engineers being changed from merely apprenticeships in order to learn the traditional methods to the teaching of science and mathematics [12]. For the last two centuries, in various debates engineers have, therefore, taken the view that their rational scientific methods were the best means to solve a problem. However, what engineers sometimes failed to recognise was that the issues at stake have changed over the last hundred years. Urban water service provision is not a scientifically/mathematically solvable optimisation problem, but a choice between conflicting norms and values. *Sheltering the hope of a technical solution for any of our problems, while not including cultural and social measures, is tantamount to walking in an imaginary land* [13]. The days when infrastructure simply meant pipes and water supply planning was all about estimated future growth in demand and, then, building more capacity to meet the demand are over.

Looking at contemporary water management challenges around Australia, it is obvious that water engineers have struggled to understand the community's needs. In the cases where engineers adopted the ultra-progressive approach to introduce wastewater recycling as a means of potable water supply augmentation, they experienced rejection by the community. When they decided to implement the less controversial option of desalination, they still received criticism for choosing an energy hungry option.

The feeling of being misunderstood, *...no matter what they did, their work being condemned anyhow; and that every solution they developed was seen as creating new problems* - is a feeling that is ironically shared by engineers throughout the world [12]. The real issue for many citizens is not the intricacies of technologies and their consequences, but the fact that experts were to decide on their acceptance, i.e. the technocratic nature of governance. This criticism that is aimed at the process, and not so much on the content of decision-making, needs to be understood in the engineering community.

Professional engineers need an awareness of sociology, scientific philosophy, economics, history, as well as other disciplines to have the basic knowledge necessary to develop a relationship with society [14]. Public authorities in the Western democratic societies are not driven by technical rationality but by political rationality; therefore, decisions for which enough support can be generated are preferred. This reality has seen the role of engineers in public decision-making being reduced to mere data generation. Influential positions in leading the public debate are held by policy advisors often from economics and/or public relations backgrounds. For the engineer, it is very important to be heard in the public debate and to possess the necessary skills for the same.

A water service provider needs to understand that the community's demands for the services he/she provides are dynamic. Developing new technologies in the laboratories of higher education institutions is not enough. Implementation of these new technologies can only take place, if the technologist has a deep understanding of the motives and desires of people that will be related to the new technology and the effects of his design on community as a whole. Interaction with customers, colleagues, politicians and others involved is, therefore, critical element that should be taught to engineering students [12]. The importance of using case studies and work experience in companies in meeting these learning objectives cannot be underestimated [14].

However, the traditional model of engineering is mono-disciplinary and assumes that graduates will work as specialists [15]. A direct consequence of this model is that students identify strongly with their own engineering discipline and are usually ignorant and often dismissive of other disciplines [16], which has been described as *disciplinary egocentrism* [17].

Disciplinary egocentrism is based on the work on cognitive development, which described *egocentrism* as a child's inability to think beyond his/her own perspective. It theorised that children lack the cognitive maturity to differentiate in some areas of subject-object interaction. Consequently, they cannot think from another's perspective, but they develop this ability over time [18]. This theory was adapted to describe problems that confront disciplinary experts in interdisciplinary environments.

While it is acknowledged that the cognitive challenges faced by a child are different from those faced by a disciplinary expert, it is, however, important to note that part of childhood egocentrism is attributed to the fact that children allocate a major share of their mental energies to the primary cognitive task of their particular stage. Primary cognitive tasks for childhood to adolescence, for instance, include: a 0-2 year old is busy with the conquest of the object, a 2-6 year old in the conquest of the symbol, and so on [19]. Similarly, it can be argued that major share of a disciplinary expert's mental energy is attributed to his/her primary cognitive task, being expertise of the subject matter.

Failure to see connections between one's own discipline and an interdisciplinary problem limits his/her ability to incorporate new ideas and practices into his/her own work. Furthermore, it also limits one's ability to contribute to larger interdisciplinary problems, believing that his/her work has nothing to do with those problems [17]. It is, therefore, critical that water engineers of the future shun any such disciplinary egocentrism, and possess the ability to understand interdisciplinary problems fully.

RENAISSANCE WATER ENGINEER AS THE PROBLEM SOLVER

Globalisation, new technologies and the emergence of competitive engineering in the post cold war era have placed increasing demands on universities to educate a new kind of engineer. This new kind of engineer must not only have the technical expertise of his/her predecessors, but also a broader understanding of the context in which he or she works. This new engineer must also have strong communication skills, the ability to adapt and change, and an understanding of the importance of teamwork and leadership [20].

Today's fast paced climate of change requires an innovative water engineer, one who is able to go beyond his/her own technical specialty and understand the broader implications of the technological solutions he/she develops [20]. True innovators are experts at taking very specific areas of knowledge (technologies, scientific discoveries, etc) and continually reframing them in broader social, cultural or political contexts [21]. A vital attribute of these innovative thinkers is the awareness *...that in order to find opportunities to act, to make a difference in the world, they must collaborate and be damn good at it* [21].

To portray the appropriately skilled water engineer of the 21st Century, one should refer back to the societal movement of 600 y ears ago, which we now know as the Renaissance. *Early Renaissance artists were routinely involved in activities that would now be called engineering, today's* (water) *engineers must delve into areas that are considered to* *be outside of engineering* [20]. Such a multi-skilled engineer, who is devoid of any disciplinary egocentrism, can be called the *renaissance water engineer*.

TRAINING THE RENAISSANCE WATER ENGINEER

In the academic world, PhD education is an integral part of the research enterprise not only in terms of furthering research goals within universities, but even more importantly by providing future researchers, technology leaders and future academics [20]. The fact that PhD graduates become the academics responsible for training future water engineers makes it critical that PhD education should provide the necessary skills for a renaissance water engineer.

Conversely, a PhD in engineering still represents a deep understanding of one technical area. Doctoral students gain experience in research methods and learn to communicate research results. The overall result is that the training that doctoral students receive prepares them to become researchers, but not necessarily academic educators and advisors or technology leaders [20]. Such a model not only results in limiting the current PhD graduates to traditional reductionist experts, it also seals the future prospects of those who will be trained by these disciplinary egocentrics once they join the academy.

A PhD degree is the pinnacle of our large and complex higher education system. A traditional PhD graduate in engineering is a reductionist, who has worked within his/her own units, and may hardly seem affected by wider social, economic and cultural considerations [22]. These are traits that are exactly opposite to a renaissance water engineer.

It has been claimed by many industry employers that PhD students are educated and trained too narrowly and that they lack key professional skills, such as effective collaboration, working in teams, organisational and managerial skills and an appreciation of applied problems. With the conventional employment avenue for PhD graduates being teaching, institutions reported that many are ill-prepared to teach and mentor [23].

It is, therefore, obvious from the above discussion that our ability to produce renaissance water engineers would depend on our ability to produce renaissance engineering academics within our higher education institutions. This fact makes it imperative to re-examine current practices in engineering PhDs. An example to highlight the linkage between training the renaissance water engineers at the PhD level and their ongoing role in promoting this renaissance further, is Dr R. Brown, a PhD engineering graduate from the University of New South Wales, Australia [24]. The thesis *Institutionalisation of Integrated Urban Storm water Management: Multiple-Case Analysis of Local Management Reform across Metropolitan Sydney* made a significant contribution towards advancing the institutionalisation of integrated urban storm water management in Sydney. This work involved case study research of local government organisations in Sydney, and highlighted the administrative inertia of local practices as a key impediment to ecosystem-based integrated storm water management [24]. What is even more important to note is that following completion of her PhD, the candidate took an academic career path to become Professor in the Centre for Water Sensitive Cities at Monash University; thereby, getting involved in training the future water leaders of Australia. This example confirms the point made elsewhere in this article that a renaissance water engineer with PhD engineering qualifications is in the best position to become a member of the academic workforce that provides a multidisciplinary approach to solving water problems to the future engineers.

CASE STUDY RESEARCH FOR RENAISSANCE WATER ENGINEERS

Transforming the profession would begin by expanding the role of an engineer from the traditional problem solver to one who can identify, define and present problems. Such an expansion would make it easier to understand the context and the ethical dimensions of the problem before developing solutions [20]. Case study research is the right research methodology for investigating a phenomenon without separating it from its context [25].

While case studies have played an important role in teaching and research in many disciplines, the case study approach is still viewed with severe scepticism in engineering. The authors believe that case study research offers great potential in training the renaissance water engineers and the engineering discipline needs to embrace this research methodology as a priority. Very few academics in the engineering schools know how to direct case study research and this lack of knowledge, perhaps, promotes resistance and scepticism towards the case study approach [26].

Referring to research on human learning, it has been documented that the case study method provides one with context-dependent knowledge that is critical in developing people from rule-based beginners to experts. *Context-dependent knowledge and experience are at the very heart of expert activity* [27]. Context-independent knowledge is the kind of knowledge delivered from text books, computers and lecture theatres. It keeps the student at the beginner's level in the learning process. On the other hand, well-chosen case studies can help the student achieve proficiency by providing context-dependent knowledge. As an acknowledgement of the importance of case studies in learning, both teaching and research in the professional schools at Harvard University are modelled on this context-dependent approach [27].

The main criticism against adopting case study as a valid method of enquiry in engineering research comes from the purists who hold the view that *...one cannot generalise on the basis of an individual case; therefore, the case study cannot contribute to scientific development* [27]. In response to this criticism, it has been argued that generalisation is only one method of scientific development and overvaluing this method results in underestimating the strength of real examples as a source of knowledge. It is important to acknowledge that knowledge that cannot be generalised and that it still adds to the collective process of knowledge accumulation in a given field [27].

From the perspective of meeting the training needs of a renaissance water engineer, the case study allows a researcher to converge into real-life situations, often challenging his/her preconceived views, assumptions, conceptions and hypotheses [27]. This proximity to reality with a multi-disciplinary learning environment constitutes a prerequisite for advanced understanding of the issue. The School of Civil and Environmental Engineering at the University of New South Wales, Australia, is one of few leading engineering schools in the country in which multidisciplinary case studies in PhD engineering education are now well established. Over the years, case study research from this School has made significant contributions to promoting sustainable urban water management [7][9][25].

CONCLUSIONS

Australia's water challenges need a new breed of renaissance water engineers who can develop advanced technological applications, while understanding the significant economic, social or ethical implications of their work. Instead of water infrastructure deliverers, they need to be water service providers who can take into account the community's capacity to accept and respond to change.

Engineering faculties in Australian universities need to get ready to train these renaissance water engineers, with the first step in this preparation being a closer look at current practices in engineering PhDs. For instance, at the Centre for Technology in Water and Wastewater at the University of Technology Sydney, research has traditionally focussed on technical aspects of sustainable water management including:

- Solid liquid separation and filtration technologies in water treatment;
- Innovative biological treatment systems for wastewater treatment;
- Membrane hybrid and nano-technology systems in water, wastewater, and storm water treatment, water reuse, and desalination;
- In-situ barrier and other systems for treatment of groundwater, surface and ground water hydrology;
- Bio solid and waste management;
- Soil/aquifer management and modification;
- Flood management and catchment modelling for flood prediction.

The Centre has acknowledged that expanding its research focus and engaging in case study research in urban water cycle management is necessary for training renaissance water engineers. This move is essential for the Centre's ability to train water engineers who will be able to deliver IWCM in Australia, and reduce the gap between technology and application. The case study research into the Beverley Park Water Reclamation Project, which is Sydney's first ever sewer-mining project is one such initiative currently underway at the Centre. In addition to the traditional engineering line of enquiry, this work is also looking at socio-economic issues, environmental management and public policy, as well as the technical aspects of this ground-breaking water recycling project.

A number of other Australian academic institutions have also focussed their research on socio-political aspects of sustainable water management. For instance, Monash University and the University of South Australia are two leading institutions in that field of enquiry. However, the incorporation of this aspect of water management in guiding research activities within engineering faculties is still limited. The engineering institutions have largely continued their disciplinary egocentric field of enquiry. This approach must change; only then can engineering institutions produce the renaissance water engineers that are so vital for Australia's future.

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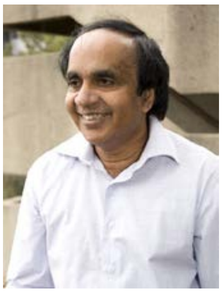
BIOGRAPHIES

Amit P. Chanan is the A/Chief Operating Officer at the NSW State Water Corporation. He is an advocate for problem-based learning for engineers and has worked closely with the University of Technology Sydney in developing their Capstone Programme. This programme provides 3rd year engineering students an opportunity to work on a real work-based problem at State Water Corporation.

Dr Jaya Kandasamy is an Associate Professor in the Centre for Technology in Water and Wastewater at the University of Technology Sydney. Prior to taking on the academic role at the university, Dr Kandasamy worked at the Sydney Water Corporation and NSW Department of Land and Water Conservation. This transition from industry to academic life provide Dr Kandasamy with a unique insight into the role case study research and problem-based learning can play in training future engineers.



Dr Saravanamuth Vigneswaran is a Professor in the Centre for Technology in Water and Wastewater at the University of Technology Sydney. He is the Director of the School of Civil and Environmental Engineering at UTS. He has published over 175 technical papers and authored two books (both through CRC press, USA). He has established research links with the leading laboratories in France, Korea, Thailand, and the USA.