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As the General Co-Chair of the 1st International Conference on Advancements in Engineering Education (iCAEED-2018), I would like to thank the Plenary Speakers, Keynote Speakers, Invited Speakers, Authors, Sponsors, Secretaries, IT Team Members, Authors, Conference Advisory Committee Members, Organising Committee Members, Technical Committee Members, Reviewers and Volunteers for making this conference successful.

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PLENARY SPEAKER

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Professor Simon Barrie, Pro Vice-Chancellor, Western Sydney University, Australia.

Topic: New developments and challenges in tertiary education: An Australian perspective

Biography: Professor Simon Barrie is the inaugural Pro Vice-Chancellor Learning Transformations at Western Sydney University. He is responsible for leadership of strategic educational innovation and transformation at the University, and as part of that work he leads the University's flagship 21C Project. This work delivers the University's commitment to ensuring its students fulfil their potential to become influential global citizen-scholars in a new technology-enabled world. Simon's passions and expertise are in innovatively engaging university communities to deliver new ways to enact the 'idea of the university' in a rapidly changing world. His research is on the transformative potential of higher education and he is a multi-award-winning teacher.

PLENARY SPEAKER

****

Mr. Md. Sabur Khan, Founder and Chairman, Daffodil International University, Dhaka, Bangladesh

Topic: Private University Sector in Indian Sub-Continent: Success story of Daffodil International University

Biography: A serial entrepreneur, Mr. Md. Sabur Khan, Chairman and Founder of Daffodil International University (DIU) and, Daffodil Education Network (DEN) has involved himself with lot of challenges while he was the President of Dhaka Chamber of Commerce and Industry (DCCI), and, the Bangladesh Computer Samity (BCS). Bangladesh government has awarded Mr. Md Sabur Khan, with the status of 'Commercially Important Person' (CIP) for his role.

His commitment has attached him as Visiting Professor with a lot of foreign universities. He has been awarded honorary professorship and honorary Doctorate degree from abroad.

World Business Angels Investment Forum (WBAF), the largest Angel investors forum designated him as the High-Commissioner of WBAF for Bangladesh. Mr. Md. Sabur Khan is the Chairman, Global Trade Committee and also Director of World IT & Services Alliances (WITSA).

Mr. Khan initiated a challenging project to create 2000 new entrepreneurs, written & published several books in two languages, and initiated business incubator, start up, venture capital, department of Entrepreneurship in the university level to promote entrepreneurship.

Mr. Khan has achieved many awards nationally, and internationally. He established 'Daffodil Foundation' for the well-being of under privileged people.

PLENARY SPEAKER

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Professor Dr Firoz Alam, Program Director, School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University, Melbourne, Australia.

Topic: An Innovated Three-Step Teaching and Learning Approach for Laboratory Experiments of Thermal Fluids Courses

Biography: Professor Dr Firoz Alam is a Professor and Program Director in the School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University, Melbourne, Australia. He earned his PhD in road vehicle aerodynamics from RMIT University in 2000 and Master's degree (combined with Bachelors) in Aeronautical Engineering from Riga Civil Aviation Engineers Institute, Latvia. Prof Alam has received numerous awards including 2004 RMIT University Teaching Award. His research interest includes aircraft, road vehicle, train, building and sports aerodynamics, energy and engineering education. He has over 250 publications. Prof Alam is a Fellow of Engineers Australia and active members of several other professional societies/associations.

PLENARY SPEAKER

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Professor Richard (Chunhui) Yang, Lead Director of Academic Program, School of Computing, Engineering and Mathematics, Western Sydney University

Topic: Engineering Education at Western Sydney University: Past, Present and Future

Biography: Prof Yang joined School of Computing, Engineering and Mathematics (SCEM) at WSU in January 2012 as Associate Professor of Mechanical Engineering and Smart Structures and he was promoted as Professor in 2018. Since 2015, he was appointed as the Lead Director of Academic Programs, Engineering and Industry Design, leading the SCEM Engineering and ID Academic Team and the curriculum review and renewal of Engineering and ID degree programs. In scientific publication, he has published more than 150 journal/conference papers and confidential reports for industrial partners in his main fields of research - Mechanical Engineering, Materials Engineering, Civil Engineering, etc., as well as in the research field of Engineering Education.

PLENARY SPEAKER

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Professor Sathaa Sathasivan, School of Computing, Engineering and Mathematics, Western Sydney University

Topic: Sydney Zoo - An experimental learning platform for sustainable water management

Biography: Prof Sathasivan has over 28 years of experience in water and environmental engineering. He has published over 100 articles and supervised 15 PhD and 20 MPhil graduates to successful completion. He has attracted over $4M in research grants and consultancies. His overall work is focussed on delivering high quality drinking water to public while minimising cost. He is the leader of Smart Water Group in Western Sydney University. His team's services are frequently sought by a number of water supply system operators across Australia ranging from large operators like Sydney Water and Seqwater (Brisbane) to small utilities such as Harvey Bay. He has strong interest in sustainable water and environmental management in urban and rural setting.

PLENARY SPEAKER

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Dr Rafiqul Islam, CEO, Solar-e-Technology, Sydney, Australia

Topic: Engineering Education in the perspective of People, Society and Sustainability

Biography: Rafiqul Islam is a mechanical engineer specializing in renewable energy technology with a Doctorate of Engineering degree in solar energy from AIT, Thailand. Dr. Islam has 10 years of tertiary engineering teaching followed by 22 years of industry R&D experience in leading positions. His engineering contributions involve researching and developing innovative and energy efficient heating, cooling and refrigeration products and processes. He authored more than 25 journal and conference articles in these areas. "Establishing lasting sustainable living environment for all" is his passion. Dr. Islam is a member of AIRAH, IIR and ASHRAE for over a decade. He is serving as the ME008 standards committee and the technical work group (TWG) reviewing the GEMS regulation 2012 for commercial refrigerated products. He was also engaged with Annex 44 work group on supermarket energy analysis for International Energy Agency in 2016-2017. He is sole inventor of 6 registered patents Dr. Islam is also principal consultant and director of the Solar-E-Technology International which successfully installed nearly 300kW of solar PV system in Australia. Dr. Islam is motivated in social outcome of all technological advancement through research for a better life of people equitably. He is an active director of Islamic Cooperative Finance Australia for 10 years who developed a real market model of equitable partnership real-estate financing method.

KEYNOTE SPEAKER

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Associate Professor Md Rafiqul Islam, School of Computing, Charles Sturt University (CSU), Australia.

Topic: Importance of cybersecurity to ICT and engineering students and professionals

Biography: Dr Islam has now over 18 years of teaching and research experience in different Universities both in Australia and overseas. He started his academic career at Dhaka University Bangladesh since I997 and worked at different Universities such as Deakin University, Monash University, CQUniversity in Melbourne, Australia. Dr Islam is now working as Associate Professor at School of Computing, Charles Sturt University (CSU), Australia. He is also Leading the Cybersecuriy research group at CSU. He has developed strong background in leadership, sustainability, collaborative research in the area of IT security, Network security and Cyber security using mixed research methodology. Currently He has a strong publication record and has published more than 115 peer reviewed research papers in different reputed International journals and International conference proceedings. He has been have been involved, as general chair, member of organizing committee & TPC, in a number of International conferences and acting as a member of editorial team of different Journals. His professional activities recognised both nationally and internationally through achieving various rewards such as professional excellence reward, research excellence award, best publication award, best faculty award, leadership award, best paper and thesis awards etc.

KEYNOTE SPEAKER

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Dr Khaled Haddad, Stormwater engineer in Cumberland Council, Sydney.

Topic: Regional Flood Estimation in Australia: Past, present and future

Biography: Dr Khaled Haddad is a stormwater engineer in Cumberland Council, Sydney. He completed his BEng(Honours), MEng(Honours) and PhD degrees in hydrology from Western Sydney University. His research is focused on regional flood frequency analysis with a particular emphasis on uncertainty and the regional modelling of large to rare floods. Khaled also has 15 years' experience in floodplain management, working on many different flood mitigation, water resources and water quality projects. Khaled was heavily involved with ARR Project 5 Regional flood methods and also made a notable contribution to ARR Project 1 development of intensity-frequency-duration information across Australia. He has published over 80 research papers, reports and book chapters on various aspects of hydrology.

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Teaching and Learning Components in an MPhil Research: Literature Review on Regional Flood Frequency Analysis

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Abstract

Literature review is an important component of the learning and teaching associated with a higher degree research (HDR) study. As a Master of Philosophy (MPhil) student in civil engineering at Western Sydney University, the first important task by the first author was conducting a literature review on her research topic - Regional Flood Frequency Analysis (RFFA) under the guidance of her supervisors. Accordingly, this paper presents challenges and opportunities in the literature review on RFFA faced by the first author. A literature review in RFFA field covers relevant scholarly journal articles, book chapters, conference papers and other relevant online sources and provides an overview, summary, analysis and interpretation of each source. Furthermore, a successful literature review interprets old researches and identifies critical knowledge gaps to create a path for a new research and outcomes. It has been found that publishing a literature review in an international journal needs significant knowledge, writing skills and commitment from the research student and his/her supervisors to make it comprehensive, complete and innovative.

Keywords: Regional flood frequency analysis, floods, probability distributions, RFFE model, MPhil.

1. INTRODUCTION

Literature review is a critical examination of previously published studies in a particular area of research. It generally covers review of relevant scholarly journal articles, research books, conference papers and many other online sources and provides an overview, summary, analysis and evaluation of knowledge that has been previously established on a research topic. Moreover, a successful literature review interprets old and recent researches and proposes questions for future research. It helps to develop a research idea and gain adequate knowledge and deep understanding of the research area. In addition, conducting a literature review helps to learn key concepts, different techniques and methods used in a specific field of research. Kordrostami et al. (2016) stated that new research students often struggle in carrying out a meaningful literature review. Furthermore, Rahman et al. (2016) examined the problem of technical writing for engineering students in Australia and found that critical literature review skills are generally poor among many engineering students. This paper focuses on literature review in flood risk assessment as a part of Master of Philosophy research of the first author.

Water is one of the most important resources on planet earth. It has played vital roles in human history and building of civilisation. But despite their benefits to humans, water also has brought numerous deaths and destruction to many communities due to lack of sustainable water resources management. For example, too much water causes flood, which is one of the worst catastrophic natural events causing deaths of human beings and animals and bringing disruptions to services and damages to infrastructure, agricultural lands and properties. Thus, it results in severe economic downturn, e.g. floods in 2010-11 in Australia caused over $30 billion damage to Australian economy. Flooding is one of Australia's costliest natural disasters, for example, in Australia, about 1.3 million homes have a flood risk rating and the estimated average annual flood damage is worth over $314 million (Australian Bureau of Statistics, 2008).

To reduce flood damage, the planers need to know flood risk at a given location. Design flood is often used for this purpose, which is a flood having a specified exceedance probability. At-site flood frequency analysis is the best method of design flood estimation which needs a long period of recorded flood data to generate meaningful outcomes. However, Australia is a large continent where many catchments have poor/no streamflow data. In such cases, Regional Flood Frequency Analysis (RFFA) is adopted, which is a data-driven procedure that allows estimating design floods at sites with short or no recorded flood data by transferring flood information from gauged to ungauged catchments on the basis of regional homogeneity (Cunnane, 1989). In RFFA, flood characteristics information is transferred from gauged to ungauged catchments. RFFA uses data from nearby sites in a defined homogeneous region to analyse flood frequency estimation at ungauged sites of interest and estimate flood quantiles at any site within this region.

Over the years, a large number of RFFA techniques have been developed around the world, with different assumptions, data requirements, and limitations. Currently, there is no universal RFFA approach that has been adopted across the world and most of them are associated with a high degree of error (Haddad and Rahman, 2012a; Haddad et al., 2012b). Therefore, the development of new and more accurate RFFA approaches are desirable to design more flood-safe infrastructures that will reduce flood damage by allowing passage of flood water safely.

As a Master of Philosophy student in civil engineering at Western Sydney University (WSU), the first author presents her experiences in conducting a critical literature review on RFFA. This aims to prepare a critical literature review to investigate both the past and recent studies on RFFA to assess the most relevant and up-to-date RFFA procedures, to explore their advantages and disadvantages, to investigate their assumptions and limitations, and finally to identify gaps and limitations with the current RFFA techniques and to propose further research in RFFA.

Recently, Rahman et al. (2015) upgraded the Regional Flood Frequency Estimation (RFFE) method in Australian Rainfall and Runoff (ARR) (the national guide) as a part of ARR Project 5 Regional Flood Methods. Therefore, based on the knowledge gained from the previous studies, the proposed research aims to propose additional recommendations to enhance the accuracy of RFFE in Australia.

The objective of this paper is to focus on the importance of the literature review as a learning and teaching component related with a Higher Degree Research (HDR), and to present the difficulties and opportunities in carrying out literature review on RFFA and in particular how this literature review has enhanced the first author's learning skills of an MPhil degree in WSU.

2. LITERATURE REVIEW

2.1. Types of Literature Review

It is important to identify the most common types of literature reviews. Uman (2011) defines the following types of literature review:

- The narrative review gives a critical summary of the literature about a particular topic. It is mainly descriptive. It describes how knowledge fits within the topic area and what relevant research has already been established.
- The systematic review identifies and synthesises all relevant studies on a particular field and it tends to reduce bias in research knowledge.
- The meta- analysis review includes statistical analysis to combine and interpret data from different studies.
- The scoping review identifies gaps in the literature and describes the necessity for further research.

2.2. Method of Writing an Effective Literature Review in RFFA

To carry out an effective literature review, the first author adopted the following methodology:

- Identify the keywords in RFFA (such as Flood, Index Flood, Homogeneity, Parameter Regression Technique and RFFA)
- Search for these keywords in the scientific databases such as Google Scholar, Science Direct and WSU library.
- Gather relevant sources to read (such as journal articles, conference papers and research books).
- Scan article title and abstract to shortlist the reading materials based on relevance.
- Understand the key concepts in RFFA, different assumptions (such as advantages and limitations for each procedure) and methodologies providing a comprehensive and deep coverage of the topic.
- Read critically, evaluate and synthesise the information in order to develop analytic arguments that lead to the research questions to be examined in the MPhil research.
- Compare similarities and differences between studies.
- Summarise findings of the relevant articles.
- Identify gaps in the literature review.
- Suggest investigations for further research need.
- Organise and structure the literature review to convey the findings of the literature review effectively.
- Prepare citations and references of each information included in the report in the required format.

Figure 1 presents a chart consisting of the main stages completed by the first author to carry out an effective literature review.

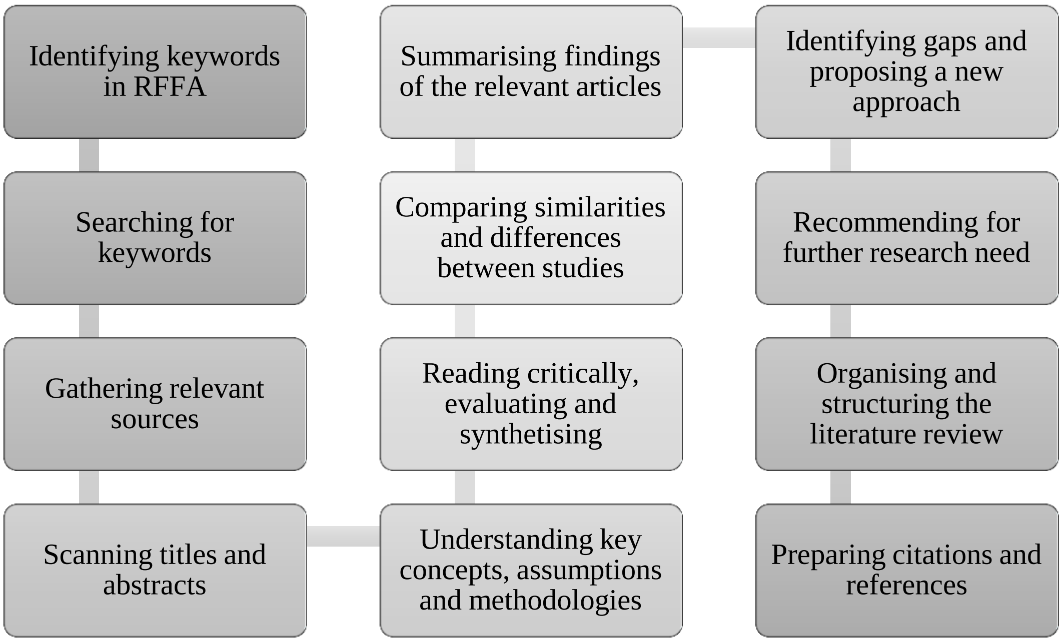

Figure 1. Stages in the literature review adopted in this study

2.3. Advantages of Literature Review in RFFA

Conducting a literature review has brought numerous benefits to the first author of this paper. It enhanced learning skills and provided significant knowledge and deep understanding of the RFFA techniques. Moreover, it gave a clear idea of the studies that have already been undertaken and created a robust foundation for advancing knowledge in RFFA. It improved critical thinking and analytical skills through identifying the similarities and differences between previous studies on RFFA. In addition, it identified gaps in the existing literature and suggested new research investigations to be undertaken in the MPhil research of the first author.

3. CHALLENGES AND OPPORTUNITIES IN LITERATURE REVIEW

Reviewing literature is an important component of academic writing and research and aims to gain an understanding of the current state of knowledge on a research topic (Davies, 2011). According to Kordrostami et al. (2016), students have found the preparation of a critical literature review as the most difficult task in their Master of Engineering degree at WSU. Therefore, it is important to highlight the challenges and opportunities that the first author has faced in carrying out the literature review in RFFA (see Figure 2).

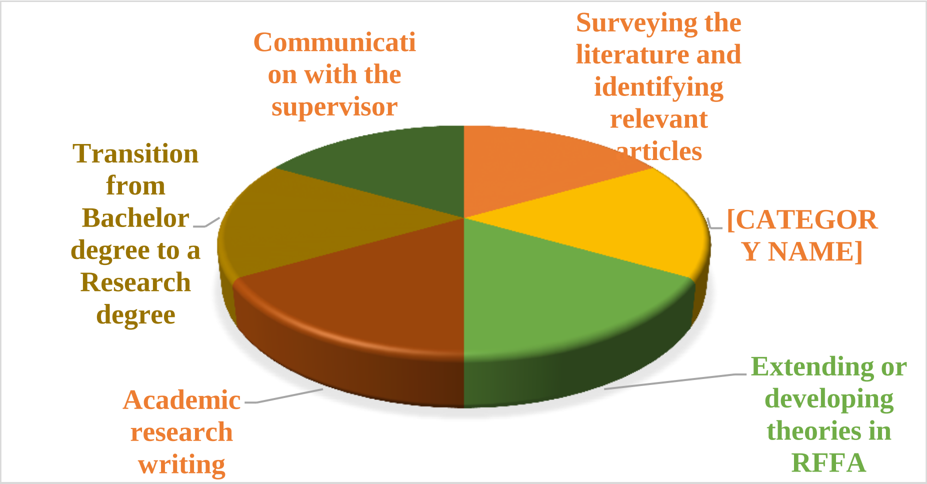

Figure 2. Aspects of literature review on RFFA

3.1. Surveying the Literature and Identifying Relevant Articles

There were too many past studies on RFFA that took significant time to screen and analyse. The first important step was finding the relevant keywords, searching for titles and abstracts containing these keywords and collecting relevant sources e.g. book chapters, journal articles and conference papers. Few issues were found to be important at this stage: relevance (selecting articles that have contributed to the main concepts of RFFA (e.g., what is generally accepted, what is developing, what is the current trends); authority (type of publication, qualification of the authors, importance and reputation of the publisher); and currency (the influence of the paper on the topic and date of publication); and grouping the collected information on headings of interests/relevance.

3.2. Understanding Main Concepts in RFFA

As RFFA was a new research area for the first author, an essential and difficult task was to deeply understand the broad concepts of the RFFA as a high-quality literature review should focus on concepts and benchmark the existing knowledge in this area. Thus, it was necessary to become familiar with the key principles of RFFA in the literature, such as Probability Distributions, Regional Homogeneity, Station Year Approach, Index Flood Method, Probabilistic Rational Method, Quantile Regression Techniques and Parameter Regression Techniques.

A summary table (Table 1) is prepared explaining the key concepts with relevant key references and important notes.

Table 1: Summarised Findings for Literature Review in RFFA

Topic	Highlight	References	Comments
Homogeneity Test	L-moments ratio H statistics Z statistics	Hosking and Wallis (1993)	Strict homogeneity could not be established for any of the Australian states.
Formation of Regions	Fixed regions ROI	Burn (1990a, 1990b) Haddad and Rahman (2012a)	ROI improves flood quantile estimates and offers more flexibility in RFFA.
Outlier Identification	Low - high outlier GB test MGB test	Grubbs (1969) Grubbs and Beck (1972) Rosner (1975, 1983) Cohn at al. (2013)	GB detects one outlier at a time MGB identifies multiple potentially influential low flows in a flood series.
Goodness of Fit Tests	CS, KS and AD tests L-moment ratio diagram	Chowdhury et al. (1991) Hosking and Wallis (1993)	Examine the fitness of the candidate regional frequency distributions.
Parameter Estimation	MOM L-moments MLE	Hosking (1990) Hosking and Wallis (1997) Martins and Stedinger (2000)	MLE and L moments have been considered as robust methods and preferable in most studies.
Flood Frequency Distribution	LP3 GEV	Cunnane (1989)	LP3 and GEV are the most preferred distributions in FFA in Australia.
PRT	Parameters of a probability distribution regressed against catchment characteristics GEV - LP3 OLS, WLS, GLS, BGLS	Tasker and Stedinger (1989) Madsen et al. (2002) Haddad and Rahman (2012a)	PRT is more appropriate than QRT. GLS and BGLS are the most used and preferred regression technique in Australia. BGLS model is preferable method of PRT. ARR (2016) has adopted PRT-LP3-ROI as RFFE Model 2016. PRT - GEV has not been tested in RFFA
QRT	Flood quantiles regressed against catchment characteristics OLS, WLS, GLS, BGLS	Benson (1962) Thomas and Benson (1970) Rahman (2005)	
IFM	Assumption of strict homogenous regions Scaling factor Coefficient of variation PWMs or L-moments	Dalrymple (1960) Ishak et al. (2011)	Large heterogeneity among Australian catchments. Results may be subject to substantial error.

3.3. Extending or Developing Theories in RFFA

Proposing new research in RFFA was challenging because writing a good literature review does not only require an investigation of the past and current theories but also should show directions for future research and recommendations. In addition, the knowledge gained from the literature review helps to propose a new approach in RFFA and to compare it with the previous procedures.

3.4. Academic Writing

Academic/research writing was a difficult and challenging task for the first author. It requires confidence and ability to write from an expert point of view. It is a challenge for most native English speakers and a common difficulty for non-native speakers of English (such as in the first author's case as a French language graduate student), due to weakness of knowledge in certain skills which are necessary for academic writing such as struggling to express thoughts and ideas smoothly, outlining, summarising, avoiding plagiarism and using the correct format of citation and referencing. According to Steiner (2011), civil engineers have a lack in effective writing skills, although they are required to write project proposals and research reports. Moreover, another study by Rahman et al. (2016) showed that many engineering students faced a significant problem in technical writing as they are unable to express their ideas in an explicit and complete fashion.

3.5. Transition from Bachelor to a Research Study

Generally, a student with a Bachelor degree has a knowledge base within a specific range. However, the transition from bachelor to research study was challenging and exciting. It is quite like an evolution from teacher-centered education to student-centered education in order to improve in-depth knowledge and significant learning experiences. There were changes in tasks and student's responsibilities. The first author believed that research student should be fully responsible for their learning, design his own learning environment and enhance new professional skills such as: deeply understanding the topic of the research, a high level of independence, critical thinking, time and project management skills, problem-solving, excellent organisation and communication skills. Moreover, the student should enhance his/her self-learning of programming skills (such as MATLAB, FLIKE software). Accordingly, Noor and Rahman (2016) discussed the necessity of practical knowledge achieved through virtual laboratories such as MATLAB software. In RFFA research, learning of programming skills are essential as this needs modelling, uncertainty analysis, data generation and Monte Carlo simulation

3.6. Communication with the Supervisor

A positive relationship between a student and his/her higher degree supervisor is a very important factor for student success. The first author argues that student should manage well his/her supervisor, develop and maintain a supportive and positive relationship in order to produce a good quality thesis. Moreover, the English language can be considered as an important factor affecting research degree. As non-native English speaker, the explored challenges were those caused by different accented English and it has been found that the main difficulty that might be faced is miscommunication between student and supervisors which is due to the struggling communication, the ability to express ideas adequately and the difference in foreign-sounding English accents. In fact, incorrect or poor sound production may lead to more comprehension problems than speech with lexical errors (Gilakjani, 2012).

Both the supervisors (second and third authors) are knowledgeable, expert and professional and are very helpful and supportive in carrying out the literature review. We met regularly even though the supervisors were busy, and we prepared a research plan and timeline for the research degree.

Furthermore, it has been learned that responsibilities must be taken during the research such as meeting deadlines, following rules, completing work with the maximum standard of moral and scientific practice and taking in seriously supervisor's advices and constructive criticisms. In addition, as an MPhil student, it is not expected to have detailed guidance for daily research, independent work is the desirable norm.

4. PUBLISHING A LITERATURE REVIEW AS A JOURNAL PAPER

During this research, it has been discovered that writing a good review is really challenging. It is not just a summary; it needs to be critical to judge whether the published results are logical and should give pathways for future research in RFFA. It should be known what has been done as well, as what could be done to make progress in RFFA. Therefore, publishing a good review paper requires a deep knowledge and a higher level of understanding plus an excellent organisation and experience than just reading and summarising. Moreover, high standard requirements should be met to be able to publish a review paper in an international journal.

5. CONCLUSION

This paper examines the importance of the literature review as a main component of the learning and teaching in a Higher Degree Research. It presents the preparation of the literature review on RFFA highlighting challenges and opportunities that have been faced by the first author and how it enhanced learning skills of his MPhil study in WSU. It has been noted that a successful literature review requires critical examinations of the previous and recent studies in a specific topic area including learning about important concepts, design methods, and techniques. In addition, it has been found that publishing a good literature review in an international journal requires significant knowledge and commitment from the research student and his/her supervisors.

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Learning Hydraulic Engineering from Site Visit and Open Book Assessment

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Abstract

Due to the introduction of computer based program and reduction of face-to-face contact hours, many higher education institutions are cutting site visits and field works from their curriculum. But engineering is an applied science to the real-world problems and the engineering education needs hands-on training. Because of this, fieldworks and site visits are essential components of engineering course curricula. Upon completion of lecture on dam engineering, a visit to a dam site was conducted for final year civil engineering students, which was followed by an open book assessment after one week of visit. In order to investigate the student learning on hydraulic engineering from site visit and its subsequent open book assessment, a questionnaire survey was conducted after the open book test. The survey instruments consist of two sections. One section has 9 questions on student learning from site visit and second section consists of 10 questions on learning from open book assessment. The results revealed that students are motivated (87% agreement; n=39) for site learning because it provides work-integrated learning experiences (also 87% agreement; n=39). It also shows that an open book assessment is an excellent way of learning to be a professional engineer (92% agreement; n=48). Student performances on site learning show that 78% of the students got mark more than 70% in the test achieving significant learning outcomes. This also indicates that the open book assessment motivates students' independent learning but there is a need to train students what information they need to bring because many of them found wasting times flipping through the site visit notes/books.

Keywords: Student, Learning, Site visit, Assessment, Open book.

1. INTRODUCTION

Hydraulic engineering is a core unit in undergraduate civil engineering course curriculum. It covers fluid mechanics, open channel flow, pumping systems, water distribution systems, sediment transport and hydraulic structures. In order to gain hands-on learning experiences, undergraduate laboratory experiments are conducted in engineering study. Laboratory experiments may provide some practical feelings but complete understandings for real-life situation remains unresolved until they go for a site visit. Many reviews have been taken place in last few decades in higher education sectors to reform engineering course curriculum. But most of the cases, it focused on the content of the subject materials and its employment opportunities in engineering industries **(**Sparkes, 1993; Simmons, 1995; Elms, 1992; Ditcher, 2001). One of the suggestions is made to improve student motivation by incorporating more problem based education. But this can happen when the learning experience is more towards student-centred rather than teacher-centred. One way of achieving this by adopting blended learning approach in teaching. For example, Rahman (2017) used this approach to teach fluid mechanics in engineering (Rahman, 2017) and Anwar (2011) used student feedback-based blended teaching in civil engineering hydraulics. But to provide more student-centred learning experiences in a practical situation, it is necessary to send students for site visit, especially for hydraulic engineering.

In many countries, it is a very common trend to cut the contact hours in case of budget constraints (Russell et al., 2000; Liggett and Ettema, 2001). This has been justified by introducing computer-based courses and virtual teaching, project-based subjects, and management courses but excluding practical studies and fieldwork (Chanson, 2000-04). The integration of technology in teaching has led to e-learning, distance learning, mobile learning and/or virtual learning. Many class rooms (lecture theatres) in the universities of developed countries are equipped with Echo360 and iSmart cameras which provide direct iLectures published in the online learning platform-Blackboard for all registered users. These online resources can provide learning experiences in virtual domain but fails to provide the feeling of actual world. The limitations of online based learning resources are explained in Chanson (2001, 2004) where he emphasised for site visit especially for hydraulic engineering.

Next, assessment and feedback mechanism are important aspects for student learning. Closed book examination is an established method of traditional assessment. The main purpose of assessment is to grade student abilities and to provide feedback. But one may argue that the open book assessment provides deeper learning (Cnop and Grandsard, 1994) and powerful contribution to student learning at higher taxonomical levels (Eilertsen and Valdermo, 2000). This is more logical for engineering units because professional engineers do not solve the problems closing the books. They use multiple resources (including design code and handbooks) to solve engineering problems. Open book test is a process of testing student understandings of real-life situations where considerable resources are available rather than recall or memorization (Feller, 1994). In order to produce work-ready graduates, open-book quizzing and examination may help preparing engineering students in a better way for the real-world operational situation where they need to take decision immediately.

In this study, student learnings from site visit and its subsequent open book assessment are investigated. The results are discussed to show how a field visit to a dam site and its subsequent open book assessment provide adequate student learning experiences in undergraduate civil engineering.

2. METHODOLOGY AND DATA COLLECTION

2.1 The unit - water systems and structures

The unit - water systems and structures is an optional civil engineering unit for final year students at Curtin University, Western Australia. This unit has two parts-hydraulic structures and water distribution systems. The prerequisites of this unit are pumps and open channel flow and hydrology and environmental engineering which are taught in the third year level. The part hydraulic structures mainly consist of dam and other structures such as weirs, spillways, culvert and stilling basins. The major portion of hydraulic structures are taught as dam engineering and its necessary components such as, drainage gallery, spillways, weirs and stilling basin. This part of the unit is taught in the first four weeks of the semester. All necessary background theories, their respective design aspects, maintenance and operation procedures are discussed in the lectures and tutorials. The lecture materials are uploaded onto the online learning management system-Blackboard at the beginning of the semester so that the student could come to the lecture looking into the learning resources before coming to the class. The lectures are carried out demonstrating the theories followed by practical design examples. The whole learning sessions are recorded (audio, powerpoint slides and video of lecturer in white board demonstration) in Echo 360 and published as iLecture in the Blackboard. All users of this unit have the online access to Blackboard and view the iLectures.

2.2 The visit to a dam site

In order to provide a work-integrated learning experience, a site visit to Victoria dam in Western Australia was organised following the completion of lecture on hydraulic structures. This dam was selected because it is closer to Curtin and consists of many structures covered in the lecture. This dam is managed and operated by Water Corporation, a state Government organisation of Western Australia. Victoria dam is located 25km south-east of Perth and situated on the Darling Scarp near Lesmurdie, and crosses Munday Brook. This is the new concrete gravity dam constructed in 1991 following the demolition of older dam located in the same place. The first Victoria dam was constructed in 1891 and was the first source of water supply in the Perth's city. But the original dam fails to maintain its safety measures especially in terms of flooding and earthquake loadings and because of this, it was demolished in 1990 using explosives. The Victoria dam is slightly upstream of the old dam. Different dimensions of the dam are as follows: crest length=285m, spillway=130m, crest width= 8.7m (non-overflow section), 1.7m (above the spillway). The dam collects stormwater in a reservoir of 9.5Mm^3 from a catchment area of 37 square kilometre. Different components of this dam include dam foundation, dam wall, intake tower, spillway, drainage gallery, and stilling basin. The downstream side dam wall consists of numerous steps that may help dissipating energies in the case of overflowing. The drainage gallery is located inside the dam body that provides the opportunity to monitor the dam performance and measure the seepage water. The seepage water measurement is an important part of dam operation. This is because the seepage water reduces the uplift pressure and thus reduces the overturning moment of the dam.

The visit was conducted in teaching week five of semester one 2016. An agreement has been signed between Curtin and Water Corporation for this site visit. A preliminary risk assessment (low risk) was prepared for this site visit and an approval was taken from the work-integrated learning (WIL) coordinator of Curtin University. The students were taken to the site by a rented bus. It took approximately 30 minutes to reach the site. Three guides from Water Corporation explain about the design, construction and operation and maintenance of the dam. The students were shown the original design and were given the opportunity to see the intake tower in a group (8 in one group). This was guided by the operational engineer of Water Corporation. The guides showed them the spillway and dam wall and explained why cracking is critical in a concrete dam. Next, they were taken inside the dam to visit the drainage gallery and to see how the pore-water pressure is relieved through the galleries to reduce the uplifting pressure. Finally they explained about the stilling basin how it is used to dissipate the hydraulic energies in case of overflowing the spillway. The dam tour took two hours and during this time, unit lecturer asks different questions to the students and the guides so that the student could link with the dam design and maintenance what they have learned in the lectures.

2.3 Data Collection

One week after the site visit (week 6), a quiz test on site visit was organised in open book format. The open book format test was introduced in this unit with the assumption that professional engineers do not solve the problems closing the book or necessary manuals. In order to investigate the student learning experiences from the site visit and subsequent open book assessment, a paper based anonymous questionnaire survey was conducted just after the test. Anwar (2012) reported the student learning experiences from a site visit but he did not identify any student motivation or work-integrated learning experiences from the site visit. In this study, Anwar (2012)'s questionnaire survey list was revised to incorporate these items. In addition, a new questionnaire survey was conducted on open book assessment. These survey questions consist of both quantitative and qualitative items. The quantitative items in questionnaire survey include 9 questions for site visit and 10 questions for open book assessment. These quantitative items are asked to answer similar to Curtin University online evaluating system-eVALUate which include *Strongly Agree (SA), Agree (A), Disagree (D), Strongly Disagree (SD) or Unable to Judge (UJ)*. The quantitative items may be summarised in terms of different learning instruments. For site visit questionnaires, these include deep understandings (Q1-Q4), assessment (Q5), motivation (Q6), learning outcome (Q7), WIL (Q8) and satisfaction (Q9). For open book assessment questionnaires, the learning instruments include motivation (Q1-Q3, Q6-Q7), assessment (Q4-Q5, Q8), WIL (Q9) and satisfaction (Q10). Out of 51 student enrolled in this unit in 2016 at Bentley campus of Curtin University, 39 students took part in the survey for site visit and 48 students participated in the survey for open book assessment. Students participated in this survey anonymously and also put their qualitative feedback if they wished to do so. The difference in student participation in questionnaire survey was because of the survey sheet printed both side. It seems some of them did not notice that it is printed both sides though it was announced.

3. DATA ANALYSIS AND DISCSSION

3.1 Student feedback on site visit

The student feedback on site visit was collected using a paper based structured questionnaire survey. Student put their feedback by ticking the most appropriate in *Strongly Agree (SA), Agree (A), Disagree (D), Strongly Disagree (SD) or Unable to Judge (UJ)*. The survey results are shown in Fig. 1. All

Strongly Agree and Agree were added together to express as parentage of agreement and all *Disagree, Strongly Disagree* feedbacks were added to get the percentage of disagreement. The results revealed that the maximum agreements (97.43%) were achieved for Q3 and Q9 respectively. It means that the lecture materials on dam engineering provided to the students were sufficient for them to understand the different aspects of a dam (Q3) and they were satisfied overall with the outcome of the site visit (Q9). However, agreements for items varied between 82-97% except the item in Q5 (76%). This item is related to the assessment of quiz test on site visit. Though this item is little low but the students' performance is fairly satisfactory (see section 3.4). However, the average agreement in all items was 88% while the average disagreement was 10%. The average agreement in different learning instruments such as deep understandings (Q1-Q4: 90.38%), assessment (Q5: 76.92%), motivation (Q6: 87.17%), learning outcome (Q7: 82.05%), WIL (Q8: 87.17%) and overall satisfaction (Q9: 97.43%) confirm that site visit in hydraulic engineering provides significant student learning. The individual analysis of each item revealed that item Q2 (*I could see the practical application of theories that I learned in the lecture)* received the highest *strongly agreement* feedback (43.58%) while item Q3 (*The lecture materials on dam engineering are sufficient to understand the different aspects of a dam*) received the maximum *agreement* feedback (66.67%). This clearly shows that the lecture materials and the knowledge they gain from the lectures provided meaningful learning outcomes when they see in practice. Many of the qualitative feedbacks revealed that *they were happy to see the theory in action* and suggested *more field visits in engineering curriculum*.

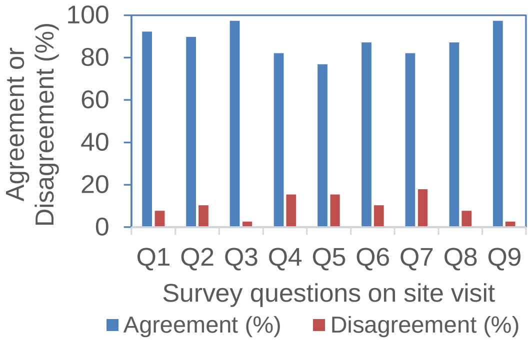

Fig. 1. Student feedback on site visit (n=39)

3.2 Student feedback on open book assessment

The student feedbacks on open book assessment were collected using a similar structured questionnaire. All feedback *in strongly agreement* and *agreement* are added together as percentage of agreement and similarly all *strongly disagreement* and *disagreement* items were added to get the percentage of disagreements and shown in Fig. 2. The results revealed that the percentage of agreements varies between 80.85-97.91% with highest agreement in Q1 (*Though the information are right there for me to look up, but still I need to study for an open book exam).* All percentages of disagreement were below 20% with a maximum disagreement (16.67%) in Q2 *(The open book exam is more challenging because it requires more critical and analytical thinking).* The minimum disagreement (2.08%) was found in Q1 and Q10 (*Overall, I am satisfied with this open book assessment).* The maximum *strongly agreement (62.5%)* was obtained in Q1 and *agreement (58.33%)* was in Q5 (*It tests your ability to find and use information for problem solving, and to deliver well-structured and well-presented arguments and solutions)*. The overall result presents in terms of different learning indicators such as motivation (Q1-Q3: 80.85-97.9%, Q6-Q7: 85.1-89.5%), assessment (Q4-Q5: 85.58-100%, Q8: 85.1%), WIL (Q9: 91.48%) and satisfaction (Q10: 97.74%). The agreement of hundred percentage in Q4 (*It tests your ability to find and apply information and knowledge in a limited time)* indicates that the limited time is a major factor for the performances in an open book test. The high percentage of agreement (91.48%) in Q9 (*Open book exam is an excellent way of learning to be a professional engineer*) shows that open book test provides them an experience to be a professional engineer which is also a form of work-integrated learning. Most of the students had positive views about the open book test as because they do not need to memorise the unnecessary stuffs (such as handbooks or standards) which they can bring to the test. The survey results clearly show that they can concentrate more on critical thinking and evaluate their own knowledge achieving deep learning. This also reduces stress of exam by not memorising the too many items of the syllabus.

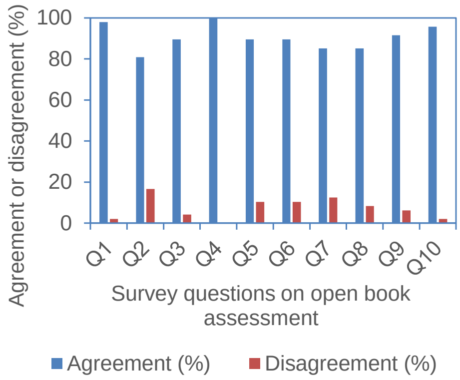

Fig. 2. Student feedback on open book assessment (n=48)

3.4 Student performances in open book assessment on site visit

The open book test on site visit was held for 40 minutes. The questions were put to test their deep understandings about the dam theory and its practical application onsite. The student performances on site visit presented in Fig. 3 are showing expected normal distribution. The results show that 90% of students got marks above 60%, 78% of student got above 70% and 45% student got above 80% of marks. These performances revealed significant student learning outcomes from site visit and open book assessment.

The results revealed that the site visit is an essential component which should be incorporated in engineering curriculum. The open book assessment may be suitable for 4th year engineering units where it needs knowledges from previous years. But it was found in this study that many students were searching information from the site visit handouts/books. The main objective of site visit was to establish link between classroom learning and site learning so that the students can understand clearly what they are learning, why they are learning. The open book test on site visit was to evaluate whether the students could understand the relationship between class room learning and site learning. In a closed book situation, the students are required to collect and memorise the information from the lecture materials and the teacher. But in open book exam, students need to know beforehand which material they need to bring to the test. This requires in-depth study of the materials and verification in the site. The students should take notes while listening to the guide onsite and later, they should cross check with the iLectures about their understandings. Sometimes it may become more challenging in open book test to find the most appropriate information if they are not well prepared. For this reason, training sessions may be organised for the students about what information they should bring to open book test. This is also a part of university learning process about what important materials they need to collect (such as, handbooks or standards) before solving/designing a particular engineering problem.

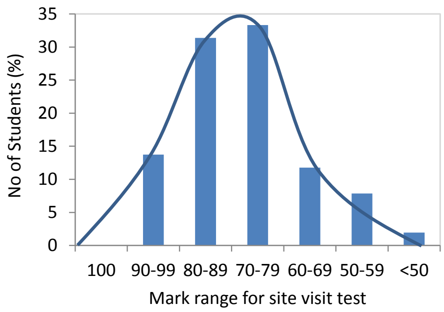

Fig. 3. Student performances on the site visit test (open book assessment)

4. CONCLUSION

In this study, learning hydraulic engineering was investigated through a guided field trip to a dam site and a subsequent open book assessment. Structured questionnaire was prepared for both items (site visit and open book test) and paper based questionnaire surveys were conducted after the open book test in the following week of the site visit. Most of the learning instruments on site visit such as deep understandings (90.38%), motivation (87.17%), learning outcome (82.05%), WIL (87.17%) and overall satisfaction (97.43%) confirmed that the site visit provided significant learning outcomes in hydraulic engineering. On the other hand, most learning indicators for open book assessment such as motivation (80.85-97.9%), assessment (85.1-100%), WIL (91.48%) and satisfaction (97.74%) also confirm significant learning outcomes through open book assessment. These results revealed that the students can see theory in practice onsite and the open book assessment provides less anxiety of memorising the theory and unnecessary stuffs (standard or handbooks). This is confirmed by the student performances which show more than 78% of students getting marks above 70%. Though significant student learning outcomes were achieved through the site visit and open book assessment, but students still need some training for prioritising the most appropriate notes that they should prepare and bring it for open book assessment.

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A Course Module for Creativity Training in Mechanical Engineering

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Abstract

It has been proposed that innovation is a process and can be conceptualized as two stages - "ideas generation" and "idea implementation". However, the factors that shape the relation between creativity and idea implementation still remain undetermined and disputed. This paper will outline what is being done on the implementation of ideas of engineering design process in mechanical engineering at Tatung University. A course module was designed to inspire students to create ideas, design thinking and product-making potential based on the knowledge of kinematics and dynamics principles. The work for idea implementation was carried out in "Kinematics and Dynamics" course at Mechanical Engineering. This course provides students with a solid understanding of the key concepts of mechanics required for design and analysis of mechanisms and mechanical devices. The present program complies with the principle of "learning by doing" with design and process techniques training based on "customer orientation".

In this program, students in groups have to make "toy" machines, which can be moved without electrical sources and motors by the end of this course. They can make the machines by various ways such as 3D printing and laser machining. These toy machines could be simple in operation, with simple game rules, and interesting and funny to play for kids. There were 40 sets of unique toy machines made by those students in the class by the end of the class at spring semester in 2017. About 200 primary students were invited to evaluate and gave the score of the designed products. Students have to present their "machine" to the faculty and kids, and leave the kids to operate this machine by themselves in a safe state. The faculty and kids gave feedback on both the mechanics of presentation as well as the practicality of the ideas.

Keywords: Implementation of ideas, toy machines, customer orientation.

1. INTRODUCTION (TIMES NEW ROMAN BOLD 14 ALL CAPS

To enhance the quality and creativity of engineering education, the Ministry of Education of Taiwan has many programs to encouraged teachers to improve their teaching techniques as reported by Chang et al (2016). For the purpose of developing students' self-learning ability, communication ability, teamwork ability, and ability of making, creating and designing, heuristic teaching method may be adopted to attract attention of students and effectively inspire studying interest of the students. The reforms in education in Taiwan (e.g., core curriculum standards; science, technology, engineering, and mathematics (STEM); Flipped classroom; Project-based learning (PBL), etc.) have attempted to address this issue (2014-2015_Education in Taiwan by Wu (2014). It has been proposed that innovation is a process and can be conceptualized as two stages - "ideas generation" and "idea implementation" (Sheppard et al (2009), Chelvier et al (2011), Vasconcelos et al (2018), Mulet et al (2017)). However, the factors that shape the relation between creativity and idea implementation still remain undetermined and disputed. The relationship between generation and implementation of ideas was investigated on the experience to openness, designing motivation and the presence of creative co-worker, which are all individually and positively correlated with idea generation.

The engineering design process is a series of steps that engineers follow to come up with a solution to a problem. The basic process model used for problem solving of a product design starts with identification of need, then goes through information gathering, idea generation, and evaluation and selection steps. Many models have been proposed to describe "the engineering design process' (Aslani et al (2012), Gericke and Blessing (2012)). Most have been developed through personal experience and accumulation of anecdotes. Our present program complies with the principle of "learning by doing" with design and process techniques training courses as "make design training". A course module was designed to inspire students in the class to create ideas, design thinking and product-making potential based on the knowledge of kinematics and dynamics principles.

2. A COURSE MODULE DESIGNED FOR ENGINEERING

The present program complies with the principle of "learning by doing" with design and process techniques training courses as "make design training". This program was proceeded through a project-based pedagogy under several interactive-learning courses and training. The make design training system includes inputs that are acted upon (processed) and produce outputs (results). The course modules, "User-Centred Design-Problem Training", were designed under the collaboration with colleagues in the Department of Industrial Design. The content of the module is listed in Table 1. We adapted several skills in this module, including Product Opportunity Gap (POG) analysis and Value Opportunity Analysis (VOA). POG analysis is used effectively to discover the current shortcomings in the existing products and future needs of the customer. A Value Opportunity Analysis (VOA) is a method that creates a measurable way to evaluate the success or failure of a product by focusing on the user's point of view. This course module is product and user oriented design training. This module was merged into the "Kinematics and Dynamics" course at Mechanical Engineering. A device and the functional properties will be selected as the object for the study and design. More importantly, emphasis is given on improving students' learning skills and creative thinking by having small group discussions.

Table 1. The course module of "User-Centred Design-Problem Training"

unit	Topics	content	Learning activity
1	●Field Observation ●Participatory Design	●POG analysis, ●VOA analysis	●To interact with the user in the field ●summarize literature ,market, field, and the opinions of users
2	Making specifications for Innovative machine	Design needed Card law	Using card law to confirm the best design for product and fabricate procedure
3	Aesthetic foundation	●Basic Aesthetic principles ●Design Thinking	●Functional product design ●Specifications developed
4	Making Skills	●Sketch training ● Machinery	●Spatial ability ●Micro-Processing
5~7	Making Innovative Machine	Wrap-up, presentation at last week	Finish making Innovative Machine at Maker space

3. KINEMATICS AND DYNAMICS COURSE AT MECHANICAL ENGINEERING

The "User-Centered Design-Problem Training" module was applied on the students with the "Kinematics and Dynamics" course at Mechanical Engineering. This course deals with dynamics of rigid bodies, the impulse-momentum method and the work-energy principle to solve dynamic and kinematic problems in mechanical systems. Students learn and apply a systematic approach to the selection, synthesis, analysis, application and evaluation of common mechanisms and machines for engineering applications. The learning outcomes of the course are that students will be able (1) to draw the free-body diagrams in plane motion with computer, (2) to understand the basic principles of work and energy, and of impulse and momentum, (3) to apply the basic methods in solving problems, (4) to explain the operation of the motion of rigid bodies, (5) to effectively communicate in oral and written.

To achieve the goal of the outcomes, a project for dynamic and kinematic system is claimed to be carried out through implementation of PBL techniques. This project topics would be selected to certify that the students would recognize. Students should submit their research portfolios and final report of the project and they also needed to show their achievements by oral presentation in a workshop. Summative assessments of student's performance as well as the effectiveness determined for taking the course was evaluated at the end of the semester. Working with groups is strongly encouraged, but all work must reflect the understanding of the student who turns it in. Students are also trained to draw up a series of realistic object designs, so as to have students verifying the previous learnt theories in class, and to reinforce the implementation of theories. We also developed different teaching materials to have students processing and assembling them in class (Fig.1)

Fig. 1 Students can verify theories and implementation in class, as well as adding the support from assistants.

4. THE MERGE OF THE COURSE MODULE

4.1. Sketch training for product design

Students were trained with spatial sketch by teachers in the industrial design sketch classes. We assessed the changes of spatial ability and drawing creativity to investigate whether spatial ability is improved together with sketch creativity. The results show that the students generally improved their spatial ability and drawing better in fluency and correctness. Drawing creativity is also improved but has no significant relation to spatial ability. As shown in Fig. 2, through practice of the sketch training has been clarified the improvement of the spatial ability and sketch skill. Students were taught to style a cube-based model and after that they were asked to realize the model by sculpturing a PU form.

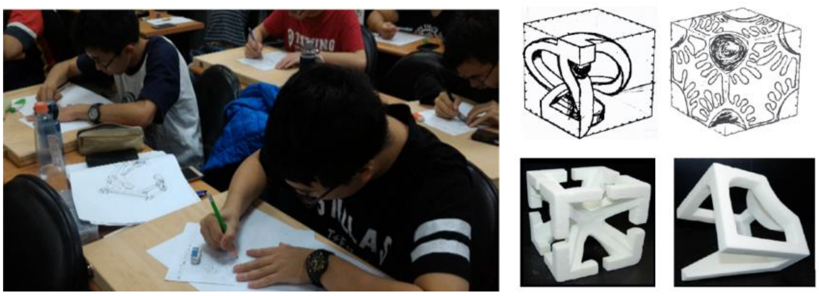

Fig. 2 Initial shape styling practice by sketch and sculpturing skill training.

4.2. Literature review, making specifications and teamwork

Students were asked to build a device or a system in teams to collect, analyse, and interpret data. The project-based work style emphasizes collaboration and is typically assigned to the team rather than to individuals. The work of a team on this step is to search and collect information and make specifications for the final project. Students have to survey books, articles, and any other sources relevant to the project. The final project under the program was to make a toy machine for kids. The specifications of the toy machine were set for students to follow. First, no battery, no motor and no electrical power are applied on the machine. Second, the machine can be operated only by hand. Third, the machine built should use cardboard and other recyclable materials. The cost of supplies for the toy machine is less than 10 US dollars. Students have to find the way to build their toy machine for kids. The course module will help students to catch the idea for the machine design. Design thinking is an iterative process where students, as a team, work their way through the process of Exploration, Creation to Implementation. As shown in Fig. 3, an adviser helped students using card law to find the way for machine design. Students can collect the information from book, literature, and internet.

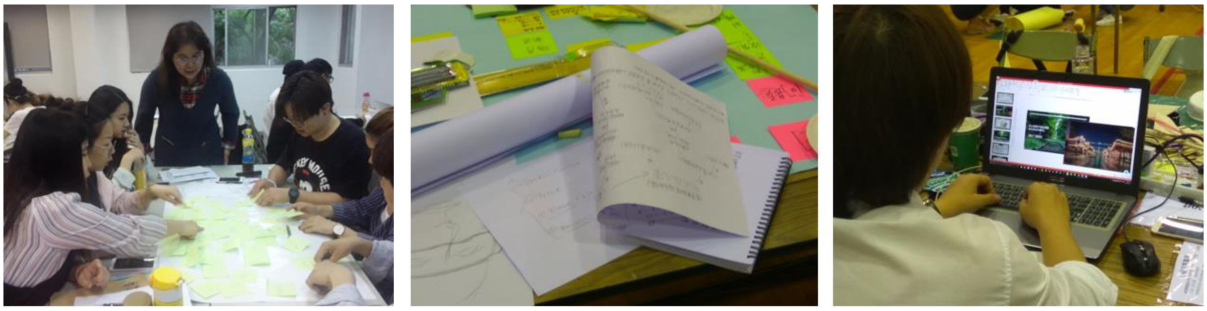

Fig. 3 The card law activity for design and information collected from book, literature, and internet.

4.3. Machinery training

Students were taught processing related skills as in “Making Skills” of the course module. Learning machineries was combined with Engineering, Micro-Processing Courses in the College of Engineering, in or to give students the opportunity to learn how to use maker machines in extracurricular period (Fig.4) Students were trained using multiple micro processing machines in this program, such as micro metalworking machine implementation and material production to in class implementation, the common 3D printing and laser ray carving processing. These trainings are for the students to have the skills to carry out the project of machine design. Meanwhile, Students who are unfamiliar with traditional metalworking machineries could use the micro processing machines to quickly build up the products and verify the designs.

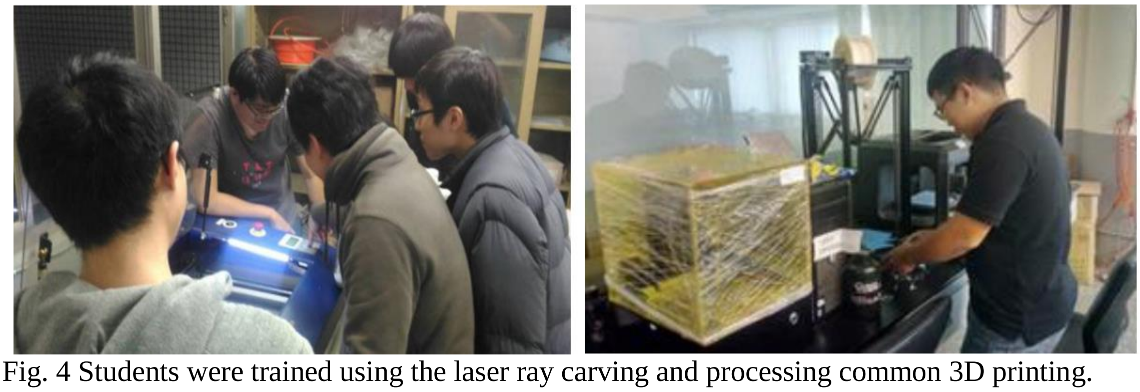

Fig. 4 Students were trained using the laser ray carving and processing common 3D printing.

5. THE PROJECT TOPIC WITH TOY MACHINES

For implementation of the course module, student could have a profound understanding of the different ideas and designing viewpoints of assignments and products when inspecting each other’s works during the interim. Additionally, after the adequate explanation from teachers and the support of the assistants, students could learn more from the experience sharing when working on the final projects. This is an indispensable sharing process for the implementation courses and students. There were 98 students attending this course and 40 sets of toy machines made. In order to design and make machine, it is important to understand how different mechanisms work. No matter how complex a machine may be, these toy machines were divided into six basic categories based on the mechanical principles for operation such as: cams (6), cranks (4), gears (7), ratchets (2), levers (31), and pulleys (12). The mechanical principles used most are levers and pulleys. This may be ascribed to the machining skills of students and type of toy machines. Typical toy machines made by students were pinball, hooting machine, fishing, 3D baseball, Robots grasping, and so on.

The final assessment for the project of toy machines was held as 'handmade toys matchup' competition, inviting 200 kids from elementary school to take part as reviewers as shown in Fig.5. We hoped that the kids could vote for the group they like after playing the 'battery and motor free' handmade toys its students built with the knowledge of manoeuvring learnt in class. For example, the 'extreme balancing platform' combines four bar mechanism, hinge, and the leverage principle. The players have to control the strength by two hands in order to make the small steel ball pass all three challenges. The product was viewed by both the elementary students and their teachers as instructive, challenging, and popular. Two other popular groups 'genius fisherman' and '3D Live Powerful Pro Baseball' were more complicated than they seem to be, implementing 'gears' to control fishing rods and the batters power relatively. 'Mad Daniel' utilized rubber torque to wave in turns. Some kids like it such that gathered a number of stickers to exchange for it, thereby winning the champion for it.

The final project competition is designed for students to display their works through the course. The works should show not only the theories, but also the possibility of implementation. The assessment of the course module focused on the report on students' final project including 'mechanical principles', 'communication', 'teamwork', 'users-centred design', and 'creative ideas'. The average score obtained in this process representation was 3.6/4.0. According to the experts' assessments, students successfully described the toy machine and the group average score was 3.8/4.0. Only 30% of the teams were ranked as *sufficient* while 70% were scored as *excellent.* Students achieved an average score of 3.3/4.0 and 3.5/4.0 in ideas and principles, respectively. More than 85% of students were able to undertake an ideation process for the team project.

Fig. 5 The on-site of 'handmade toys matchup' competition', primary school students concentrated on playing the toy machines.

6. FINAL REMARKS

Introducing engineering designing process through the course module enables students to see how the fundamental concepts of science and math can be applied to complex engineering design. Students have more confidence to deal with the problems after training with the design-based course module. In addition, students are more willing to discuss and share their ideas with team member and advisor. It was widely accepted from students' comment that the merge of the design-based course module made the course more lively and interesting. The course module make them to think about the applications of mechanical principles and course objectives. We found the merge of the design-based course module actually promote the learning of student effectively.

During the process of the course, software and hardware resources should cooperate. Adding mathematical software and designing software guides in to courses could promote students to solve related mathematic calculations and prevent design interfering. As of hardware support, the teachers' professional designed model products could improve the students' 'learning with implementation' idea during the operation and processing in class. When the students produce and display their final projects, the school would also be obliged to provide funds and places to render the class perfectly.

7. ACKNOWLEDGMENTS

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Developing Engineering Management Knowledge and Skills through Postgraduate Education in a Blended Learning Environment

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Abstract

The University of Southern Queensland delivers a number of coursework postgraduate engineering programs to technologists wishing to upgrade their qualifications and qualified professional engineers desiring to develop their engineering knowledge and skills. As well as technical engineering courses, these programs offer a number of courses in engineering management. These courses teach engineering management knowledge and skills in topic areas like asset management, project management and risk management. All are taught in a blended learning environment, in which on-campus classes are delivered to learners who study at the University's main campus at Toowoomba, Queensland and online course materials are provided to learners who are primarily part-time, are often engaged in industry and are located throughout Australia and internationally. All learners use a common interactive Study Desk on which material is made available by the teaching team. This material includes printed study material, lectures, tutorials, readings and videos. A challenge in effectively delivering these courses is to meaningfully engage a wide range of learners who study in different modes, and who have a range of educational and work experiences. The approach used to achieve this goal is to utilise good teaching principles, such as student centred learning, authentic assessment tasks and experiential learning processes. While these methods have been quite successful at engaging learners, there are also other opportunities for improving learner interaction and development. One approach that is currently being used is to utilise industry guest lecturers, using high quality recorded video communication that is delivered at a time selected to best suit online learners. There are also opportunities to develop additional real world examples, use advances in information systems for tasks like simulation of real projects and processes, utilise data analytics to improve the assessment and development of learner engagement, and make other improvements.

Keywords: Engineering, Postgraduate, Management, Blended Learning,

1. INTRODUCTION

In addition to delivering undergraduate engineering programs, the University of Southern Queensland offers coursework postgraduate engineering programs to technologists who desire to upgrade their qualifications; and to qualified professional engineers desiring to further develop their engineering knowledge and skills. These programs include a number of engineering management courses, which largely focus on developing the professional skills of their graduates, in areas like asset management, project management, risk management and innovation management. All of these courses are taught in a blended learning environment, in which on-campus classes are delivered to learners studying at the University's main campus at Toowoomba, Queensland, and online course materials are provided to learners who are primarily part-time and are often working in industry, and may be located in Australia or internationally.

These courses accordingly form a key component of meeting the professional skills requirements of graduate professional engineers, such as understanding sustainable engineering practice, applying systematic approaches to the conduct and management of engineering projects, and exhibiting professional and personal attributes related to engineering practice (Engineers Australia, 2013).

While these courses are primarily offered in the postgraduate coursework study programs of the Master of Engineering Science and Master of Engineering Practice (University of Southern Queensland, 2018), which are designed to enable engineering technologists to meet professional engineering requirements, they are also offered in advanced programs like the Master of Advanced Engineering (University of Southern Queensland, 2018), which is designed for existing professional engineers to further develop their professional knowledge and skills, and the Doctor of Professional Engineering (University of Southern Queensland, 2018), in which learners undertake eight courses as part of a professional doctorate program. The Doctor of Philosophy (University of Southern Queensland, 2018) also requires study of one of these courses, usually in advanced engineering project management, along with a research methodology course.

The three Master level programs are designed to comply with Australian Qualifications Framework (AQF) Level 9, which requires graduates to "have specialised knowledge and skills for research, and/or professional practice and/or further learning" (Australian Qualifications Framework, 2013). In addition, the purpose of the Masters Degree (Coursework) "is to qualify individuals who apply an advanced body of knowledge in a range of contexts for professional practice or scholarship and as a pathway for further learning" (Australian Qualifications Framework, 2013). The Doctoral programs are designed to meet the requirements of the Australian Qualifications Framework (AQF) Level 10, the graduates of which "will have systematic and critical understanding of a complex field of learning and specialised research skills for the advancement of learning and/or for professional practice." The specification for AQF Level 10 advises that both there two forms of the Doctoral Degree with the same descriptor within the Doctoral Degree qualification: the Doctoral Degree (Research), of which the Doctor of Philosophy is an example, and the Doctoral Degree (Professional), of which the Doctor of Professional Engineering is an example (Australian Qualifications Framework, 2013). The courses in the postgraduate engineering management curriculum at the University of Southern Queensland, which aim at offering advanced study options and the development of critical thinking, have been designed to meet the academic requirements of these programs.

Because they are offered in advanced engineering programs, these courses in the are usually designed to at least partially address the role of the experienced professional engineer, who is responsible for "bringing knowledge to bear from multiple sources to develop solutions to complex problems and issues, for ensuring that technical and non-technical considerations are properly integrated, and for managing risk as well as sustainability issues" (Engineers Australia, 2013). All are delivered in a blended learning mode (Oliver and Trigwell, 2004; Learning and Teaching Unit, University of Western Sydney, 2013), which combines on-campus teaching to learners attending classes at the University and online delivery to learners studying externally to the University,

In designing these courses, there has been a focus on good design and delivery of them, including a clear purpose, alignment with external requirements, and alignment of course material with objectives, good teaching and assessment practices, and continuous improvement. At the same time, there are opportunities to improve these courses and the way in which they achieve their objectives.

The objectives of this paper can therefore be summarised as:

- Discuss the design and delivery environment for these courses
- Discuss how well the design and delivery of courses have met the requirements of learners
- Briefly discuss how the engineering management curriculum may be enhanced in the future.

These objectives are discussed through a literature review of the main development criteria for engineering management courses, discussion of course design and delivery for two selected courses discussion, and potential future course enhancements.

2. LITERATURE REVIEW

2.1. Professional skills requirements of engineers

Professional skills may be defined as the skills necessary for graduates to succeed in professional practice and include generic skills; personal attributes like motivation; and the ability to understand ethical conduct, meet deadlines, be punctual, relate well to others and show initiative (Crebert et al, 2011). For example, the professional competencies that qualify students as professional engineers at the Stage 1 or graduate level (Engineers Australia, 2013) are listed in three sections – knowledge and skills base, engineering application ability and professional and personal attributes. While the knowledge and skills base primarily relates to technical skills, engineering application ability focuses on applying the skills, and the professional and personal attributes relate to professional and personal conduct. These professional skills are further underpinned by the Engineers Australia Code of Ethic (Engineers Australia. 2010), which defines the values and principles that shape the decisions that engineers make in engineering practice, and requires professional engineers to demonstrate integrity, practise competently, exercise leadership and promote sustainability.

The Engineers Australia requirements for the experienced professional engineer at the Stage 2 competency level, who requires at least three years' experience as a graduate engineer, requires them to demonstrate sixteen sets of professional competencies, that are grouped into the categories of personal commitment, obligation to community, value in the workplace and technical proficiency (Engineers Australia, 2012). Example competencies that are relevant to engineering management include developing safe and sustainable solutions, engaging with stakeholders, identifying and managing risks, meeting legal and regulatory requirements, taking action, exercising judgment, problem analysis, exercising creativity and innovation and evaluation (Engineers Australia, 2012).

2.2. Engineering Management Course Design and Delivery Requirements

In developing courses, a first step is good design of the curriculum, which can be considered as the knowledge and skills students are expected to learn. Using as their basis a model cited by Biggs (2003), Meyers and Nulty (2008), for example, have outlined five principles for curriculum design that are designed to maximise learning outcomes. Thus curricula should be authentic, real-world and relevant; constructive, sequential and inter-linked; require students to use progressively higher-order cognitive processes; be aligned with each other and the learning outcomes; and provide challenge, interest and motivation to learn. The Centre for Teaching and Learning, Queen's University of Ontario (n.d.) have identified a continuous improvement process for a curriculum consisting of the steps of set goals and resources; develop and validate program learning outcomes; gather, discuss and interpret evidence; improve and enhance; and monitor and adapt.

Courses should also be designed, developed and delivered in order to achieve good teaching practice. An example of such approaches is student centred learning, which focuses on what the learner does; encourages learners to undertake learning to achieve learning objectives; and uses an aligned instruction approach (Biggs, 1999). Other good teaching practices include authentic assessment (Gulikers et al, 2004), a form of performance criterion-referenced assessment that is aligned to academic instruction and requires learners to demonstrate their competencies in a setting that resembles professional practice; and experiential learning (Kolb, 1984) that uses a cycle of concrete experience, reflective observation, abstract conceptualisation and active experimentation. A final consideration in course design and delivery is the requirement that as all courses in the programs offered by the University of Southern Queensland are delivered in a blended learning mode.

In summary, the development of engineering management knowledge and skills that meet the requirements of Engineers Australia requires the development of specialist discipline based engineering knowledge, understanding of generic engineering management skills and understanding of the Engineers Australia Code of Ethics (Engineers Australia, 2010). To be of value to both the technologist upgrading their qualification to that of a professional engineer, and the existing professional engineer seeking advanced knowledge and/or qualifications, postgraduate engineering management courses should not only meet Stage 1 professional engineer requirements, but also aim to partially meet Stage 2 competency requirements. They should also meet any applicable standards.

Similarly, the courses in the engineering management curriculum are required to be designed, developed and delivered in a blended learning environment, and encourage learners to achieve the objectives of the curriculum through a combination of quality campus and online teaching. This curriculum should be reviewed and modified periodically through a continuous improvement cycle.

The following research questions have therefore been proposed:

- Does the design, development and delivery of the postgraduate engineering curriculum meet professional requirements and standards?
- How well does the teaching of this curriculum achieve quality learning in students?

3. ASSESSMENT OF DESIGN AND DELIVERY OF COURSES IN THE PROGRAM

3.1. Assessment of Course Design and Delivery

The design of the courses in the engineering management curriculum aims at effectively teaching, in a blended learning environment, relevant technical and professional engineering requirements, including the use of applicable standards, which at a minimum meet the requirements of Engineers Australia Stage 1 competencies, and where possible develop the learner beyond this level. Such development is achieved though adopting a strategic, life cycle point of view, and closely addressing managerial aspects of the course subject matter such as stakeholder engagement, sustainability and risk. The normal approach to design of the course content is to consider the topic as a whole, then break it down into its component parts, usually using a framework, such as one based on a strategic life cycle context. As wide a professional engineering field as possible is covered.

The delivery of these courses varies with the course, its learner cohort and its assessment approach. Learners are encouraged to think and reflect about their subject matter, use practical examples, consider the whole as well as the component parts of a course topic and undertake challenging assessment tasks that are authentic as possible and require learners to apply the principles in the course in a practical engineering context. Where possible, an experiential learning process, that aims to use feedback from a previous assessment task in a subsequent assessment task, is used. All learners use an online Study Desk, which contains written course material, selected course readings, lecture presentation and other aids such as recorded lectures, readings, postings of useful material and video presentations. Assignments are also submitted electronically through the Study Desk, which is structured to meet learner requirements, and allows learners to post queries for response by teaching staff. It is also the portal for assignment submission. Tutorials and reflective exercises supplement course delivery. The increasing use of video conferencing in these courses aims to reach learners who cannot attend class. The two courses of Management in an Engineering Environment and Advanced Engineering Project Management further illustrate the application of these principles.

3.2. Teaching - Asset Management in an Engineering Environment

Asset Management in an Engineering Environment (University of Southern Queensland, 2018) adopts a strategic life-cycle approach to managing engineering assets and has a strong sustainability emphasis. It initially teaches theoretical asset management principles (introduction to asset management, the asset life cycle and engineering economics) and then applies these principles to asset maintenance and operations, integrated asset management and asset management systems, before concluding with a discussion of emerging issues. This course, which was first offered in 2004 as an online course only, had 86 learners enrolled in 2018, of which 45 studied online. It is assessed by a single assignment worth 50%, and an examination.

The main question in the assignment asks learners to assume the role of an asset manager who has been tasked to manage a middle level engineering asset that has a significant number of engineering, financial, stakeholder and other issues. They are also tasked with developing a plan, using a strategic life cycle approach, to achieve best practice in this process. Other questions in the assignment ask learners to apply the principles of engineering economics to selecting the best option between the two alternatives of replacement or rehabilitation of an aging engineering asset, and to apply depreciation principles to an asset over its life cycle. The examination primarily asks learners to apply principles learnt in the course, using example engineering applications nominated by the learners. This approach combines student centred learning and authentic assessment approaches, and as much as possible utilises experiential learning approaches. Learner evaluations of the latest delivery of this course are positive, and include comments such as: "It's really a useful subject." There were also some comments relating to potential course improvement, such as: "More information would have been helpful relating to asset economics."

Over time, this course has undergone continuous improvement. For example, electrical engineering examples of application of the principles in the course have been extended from an original civil and mechanical engineering base. The release of the international asset management standard (Standards Australia 2014) has required further updating of the course. One weakness of the course is that, being strategic in nature, it does not deal with asset operations and maintenance in the detail required by practitioners in this area. A companion course, Whole of Life Facilities Management (University of Southern Queensland, 2018), more closely addresses this topic.

3.3. Teaching - Advanced Engineering Project Management

Advanced Engineering Project Management (University of Southern Queensland, 2018) teaches advanced issues in project and program management, through firstly teaching theoretical principles and then discussing their application to more advanced concepts. Topics taught in this course include the project life cycle, the project management knowledge areas in the Project Management Body of Knowledge (Project Management Institute 2017), project sustainability management, attributes of a project manager, managing complex projects and program management. This course concludes with a discussion of alternative project delivery methodologies and future issues in project management.

Assessment in this course, which was initially offered in 2014, is through two assignments. The first assignment (worth 40%) requires the learner to restore good project management practices to a poorly managed project that the learner has recently taken over. Feedback from this assignment is then applied by the learner to the second assignment (worth 60% of marks), which asks the learner, now in the higher role of a program manager, to perform a similar task with respect to a number of projects. In all cases, the learner nominates the projects that are discussed. Thus this course combines the teaching principles of student centred learning, authentic assessment and experiential learning. In 2018, this course had an enrolment of 105 learners, of which 48 studied online.

While this course has good overall learner evaluation and attracts good comments such as a "structured approach to learning the principles of project management ", on-campus learners tend to rate it more highly than online learners. One reason for this view is that, because of their practical knowledge of project management, some online learners find it difficult to adequately describe project management processes in the word limit for the assignments. This area will be addressed in future course offers.

4. DISCUSSION AND CONCLUSION

Based on the above discussion, the first research question with respect to how well the design, development and delivery of the postgraduate engineering curriculum meets professional requirements and standards can, using the two courses discussed as examples, be answered in the affirmative. Ongoing revision and improvement are, however, required to ensure currency with both Engineers Australia requirements and professional practice, including industry standards and emerging issues. With respect to the second research question on achieving quality learning through the postgraduate engineering curriculum, positive learner feedback to the two courses discussed, along with a commitment by teaching staff to continuous improvement and ongoing good course enrolments, indicate that the teaching of these courses has achieved quality learning in students. Learner feedback has also indicated the desirability for further improvement in future course offers.

While a limitation of the discussion in this paper with respect to the engineering management curriculum at the University of Southern Queensland is that only two courses in this curriculum have been discussed, it is considered that they are representative of the postgraduate engineering management curriculum at the University as a whole. Thus, good curriculum design and development, positive delivery in a blended learning environment and close attention to learner feedback are considered important in delivering a positive engineering management curriculum that is well designed, meets technical and professional requirements, and above all delivers positive learning outcomes to support the delivery of the programs in which they are offered, at the required AQF level.

Proposed future developments include an increasing use of guest lecturers, ongoing expansion of video conferencing, increased use of data analytics to better monitor learner interaction with the online Study Desk, use of additional real world examples in the courses, use of advanced information systems for simulation of real projects and processes, and attention to future issues such as the changes in competencies for professional engineers as a result of the increased use of artificial intelligence and more efficient approaches to data collection and interpretation have considerable potential to further enhance this curriculum in the future.

It is concluded that, using the courses discussed as example, the engineering management curriculum at the University of Southern Queensland is generally achieving positive learner outcomes through close attention to the design, development and delivery of courses in a blended learning environment, but that a commitment to ongoing improvements and enhancements, along with an understanding of current and emerging issues, is required to maintain and enhance good results for learners and the engineering profession.

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A Reflection on Master of Engineering Project – a Case Study in Western Sydney University, Australia

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Abstract

Master of Engineering Project (MEP) is one of the core subjects in Master of Engineering program in Western Sydney University. This subject aims to consolidate the entire study over two years and allows a student to develop necessary skill sets and learning capabilities in a specialised field to devise an innovative solution to a given problem. In this paper, the authors present their learning and teaching experiences in MEP, where the first author completed his MEP as a student under the supervision of the second author. It has been found by the first author that a blended learning approach assisted him in completing the MEP successfully with the production of two refereed conference articles based on his MEP. The second author identified that many of the MEP students had notable lacking in research writing which prevented them from producing refereed publications based on their MEP studies.

Keywords: *Master project, blended learning, hydrology, statistical method.*

1. INTRODUCTION

Master of Engineering program in Western Sydney University (WSU) is a two-year full-time study. A student intending to be enrolled in Master of Engineering course must have completed a relevant Bachelor degree course. Master of Engineering Project (MEP) is one of the core subjects in Master of Engineering program in WSU. MEP spans through two semesters and is a problem-based subject. A student requires completing an oral presentation and a final thesis under the supervision of a WSU academic who is a subject matter expert. The specific learning outcomes for MEP in WSU are shown in Table 1 from the subject Learning Guide. It shows that the student undertaking MEP should be able to complete a mini-research project involving literature review, data analysis and thesis writing under the supervision of an expert in the relevant area of research.

Table 1: Learning outcomes from Master of Engineering Project (MEP)

	Learning Outcomes
1	Critically analyse literature in relevant area to identify potential research problems.
2	Identify and propose research questions and hypothesis based on literature review.
3	Justify the research proposal in relation to its significance in literature and its anticipated impact.
4	Develop a plan and methodology to conduct research on an identified question/issue/problem.
5	Express ideas, concepts, arguments and conclusions in a professional report.
6	Communicate ideas and plans at a professional level through an oral presentation.

MEP aims to reflect and consolidates the entire study of the degree and develops skill sets and learning capabilities in a specialised field such as hydrology in civil engineering. For students aiming to progress further in hydrology as a specialised field, grasping concepts of hydrology is somehow difficult due to its empirical and conceptual nature. General difficulties experienced in learning hydrology for civil engineering students have discussed in numerous researchers (e.g. Elshorbagy, 2005; Aghakouchak and Habib, 2010; Ngambeki *et al*., 2012; Rahman *et al*., 2016).

This paper reflects the learning experiences throughout studying MEP in WSU by the first author and the subject-matter expert/supervisor's teaching perspectives who is also the second author of the paper. Traditionally, due to the limitation of knowledge and skill set of the students, learning and teaching approaches are dominated by the teacher-centred approach with a combination of lecture, readings and assignments (Thomson *et al*., 2012). The students are able to locate the available resources with the guidance provided by the supervisor. The traditional approach and learning method applied in project-based subject limit the opportunity for students to actively explore the given field of knowledge and being less creative. Also, with the rapid advancement in technology especially in the field of engineering, the traditional approach provides less flexibility and less emphasising on contemporary skill building.

With the project-based learning applied to MEP in WSU is dominated by blended learning approach where students are inspired and encouraged to explore unanswered questions and also connects the specific research questions/problems with the knowledge learnt in the relevant subjects completed by the students. A student meets with his/her supervisor once a week/fortnightly and discusses the learning difficulties and sets milestones/goals, e.g. completion of a literature review, writing of methodology section of the thesis. The blended learning approach consists of face-to-face lessons and online components as noted in Rahman (2017), Rahman (2016), Kordrostami *et al*. (2016), Ahmed *et* *al*. (2016) and Rahman *et al*. (2016). Students are also benefited from the combination and adoption of new technology in a relevant laboratory during the study in WSU as noted by Noor and Rahman (2016). The study of MEP provides a combination of theories and practical case studies which benefits students in lateral thinking and problem-solving. The new technology and method applied in the study enhance the skill set of the students which most likely to be re-applied in future study and professional careers.

2. REFLECTION OF THE LEARNING EXPERIENCE

Studying MEP in WSU consists of two stages. At the start of MEP, students are required to select the topics of interest with preferred academic staff. Students are encouraged to approach prospective supervisors to discuss the topic and to know study options and based on the meeting's outcome, a student and the supervisor discuss the most appropriate topic based on strength and weakness of the student. As a civil engineering student, there are opportunities for career progressions in areas such as geotechnical, environmental, water and structural engineering). It is important for a student to select an appropriate topic (e.g. relevant to his area of interest and having relevant background knowledge) and approach prospective supervisor to seek guidance, e.g. what sort of work will be needed for a given topic (e.g. laboratory experiment or computer simulation).

Throughout the study of MEP in WSU, the first author received continuous guidance from the supervisor (the second author). The research topic selected by the student was on statistical hydrology where the student has little expertise, but the supervisor is a leading expert having nearly 400 publications. The weekly meeting was organized at the time convenient to both the student and supervisor either by face-to-face or via skype/telephone/zoom. This flexible arrangement allowed the student to be more effective in learning and seeking guidance on an emerging research issue as and when needed. This blended learning approach created effective communication channels which were more effective compared with the traditional learning method.

The adopted learning method in MEP is also unique and more useful to students as it is a student-centred approach. Traditional learning methods in hydrology include lectures, tutorials and assignments. However, MEP is a problem-based subject where a student takes the main responsibility in learning, while the supervisor acts as a facilitator/guide. Instead of providing a set of predefined answers to a given problem by the supervisor, a series of open-ended responses are provided, which allows students to be inspired and exploring by the students themselves. As discussed previously, there are difficulties for a civil engineering student to explore and progress in the field of hydrology, which requires knowledge from various disciplines like statistics, hydrogeology and physics. The supervisor is the critical element in the learning as he/she can help the student in interpreting the results of statistical hydrology, which is not well-understood by early career researchers in this field.

Another distinct advantage from advanced learning method is the skill set development. With the advancements in technologies in the field of engineering, there are increased opportunities to use modern programming platform for performing engineering calculations. The study of MEP adapted the most advanced software in practice and dealt with the real world problem. Students are encouraged to learn the new skill set of programming for the field of interest. The combination of the theoretical framework and practical problem-solving skill provide a better learning curve for students.

3. STUDENT'S PERSPECTIVE

The study of MEP by the first author (student) on statistical hydrology required the skills from programming, hydrology data management and statistical analysis. To fulfil the requirements shown in Table 1, the student required to act actively in researching and to be more creative in defining the methodology for the research project. It resulted in academic concepts becoming more apparent, and student gained an in-depth understanding of the theoretical framework during the process. The student implemented the following framework in completing his MEP:

- To complete a literature review to know the latest research in partial duration series frequency analysis approach as applied to flood and rainfall analysis and to identify research gaps and formulate the research questions to be addressed in the MEP.
- To select a study area and collate streamflow data.
- To write codes in R to extract partial duration series flood data at the selected gauging stations.
- To fit a suit of probability distributions to the partial duration and annual maximum flood series data at each of the selected stations.
- To compare the estimated flood quantiles by the two methods and discuss the possible reasons for the apparent differences.
- To write a thesis and submit for examination.
- To write refereed conference papers based on the thesis; two papers have been prepared including this one.

To further illustrate the framework, Figure 1 and Figure 2 represent results from one particular site from MEP study. Figure 1 estimates for Station 201001 in NSW using Peaks-over-threshold (POT) model based on 54 years' recorded data. The exponential distribution was used to fit varies POT data series with the comparison to the observed floods based on POT 5 model. With the same methodology applied in Flood Frequency Analysis (FFA) using Annual maximum series (AMS), Figure 2 represents the data fitting using normal (NM), log-normal (LN), gamma and generalised extreme value (GEV) distributions, in which comparing to the observed floods using the same methodology.

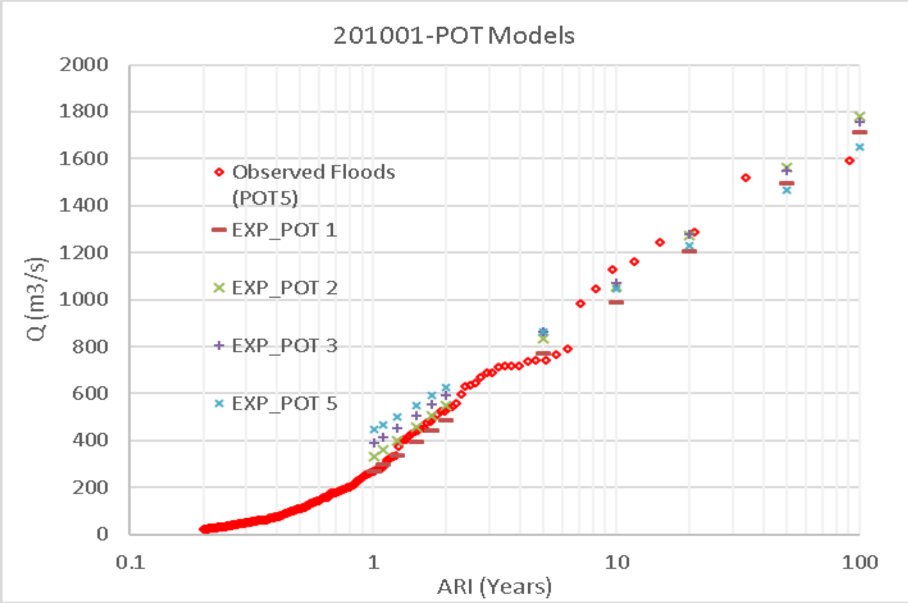

Figure 1: Flood estimates for Station 201001 in NSW using POT models based on 54 years' recorded data (1958-2011)

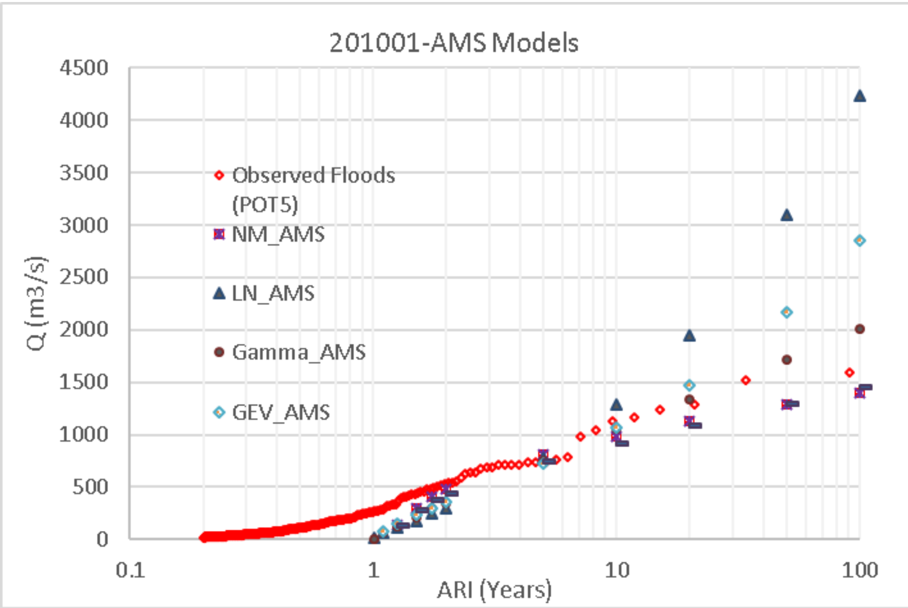

Figure 2: Flood estimates for Station 201001 in NSW using AMS models based on 54 years' recorded data (1958-2011)

The student conducts FFA based on two approaches using AMS and POT models with the streamflow data from ten catchments in New South Wales, Australia. It has been found that with AMS approach, generally at higher Average Recurrence Interval (ARI), logistics distribution fits the observed flood data relatively better. All the distribution functions used in AMS approach show a poor fit for the smaller ARIs. It has also been found that The POT 1 fits closer than other POT models for smaller ARIs, and POT 5 provides a fitting to the observed flood data series for higher ARIs. Table 2 represents a summary of the best fit of selected sites using AMS and POT models.

Table 2: Summary of Best Fit of selected sites using AMS and POT models

Site	Best POT Model		Best AMS Model		Record Length (Years)	Catchment Area (km2)	Period of Record
	ARI <5 years	ARI > 5 years	ARI <5 years	ARI > 5 years			
201001	POT 1	POT 5	All poor fitting	Gamma	54	213	1958-2011
201005	POT 1	POT 1	All poor fitting	Normal	28	111	1958-1985
202001	POT 3	POT 5	All poor fitting	Logistics	26	34	1972-1997
203002	POT 3	POT 1	All poor fitting	Logistics, GEV	27	62	1977-2003
203005	POT 1	POT 5	All poor fitting	Logistics, Normal	26	702	1982-2007
203010	POT 3	POT 1	All poor fitting	Logistics, Normal	26	179	1986-2011
203012	POT 1	POT 5	All poor fitting	Logistics, Gamma	27	39	1978-2004
203014	POT 3	POT 5	All poor fitting	Logistics, Normal	25	223	1987-2011
204008	POT 1	POT 5	All poor fitting	Log-Normal, GEV	29	31	1983-2011

Finally, studying MEP in WSU provided an opportunity for the first author (student) to publish his work along with his supervisor, e.g. Pan and Rahman (2018) has been accepted in an ERA ranked B conference. It can be stated that student clearly met the learning objectives (Table 1) in MEP where he acquired the knowledge of advanced statistical hydrology, R programming and research writing. This will be useful to the student's further study/career progression.

4. THE SUPERVISOR'S PERSPECTIVE IN TEACHING MEP

The second author has supervised over 40 students in their MEPs during his 16 years' of academic career at WSU. Although the name of MEP was changed a few times in WSU, it essentially contained a critical literature review, data analysis/modelling, oral presentation and thesis writing. In his view, only about 20% students out of these 40 students he supervised were well prepared in undertaking MEP. The remaining 80% of the MEP students had notable difficulties in completing MEP. The major lacking in students included poor academic/research writing skill where student missed the opportunity to present his/her work in a professionally competent manner in the final thesis. The inconsistencies in writing, poor grammar, connectivity and referencing were a major issue.

In many cases, too much editing was needed by the supervisor to bring the thesis to a passing standard. The student often missed in-depth discussion by comparing his/her results with similar studies published in scientific literature. Many students could not publish their theses as refereed papers. However, the first author of this paper was an exceptional student who was self-motivated and completed MEP at an exceptional level that resulted in two refereed publications.

5. CONCLUSION

This paper reflects the learning experience of the first author in completing Master of Engineering Project (MEP) in WSU. The advanced learning and teaching methods using a blended learning approach along with motivation by the supervisor and adherence to a well-developed theoretical framework resulted in successful completion of MEP by the student. Throughout the study of MEP, all the learning requirements shown in Table 1 were fulfilled by the student at a professional level. As a result, the student gained advanced skills in programming, technical writing, data management and statistical analysis. Consequently, the student wrote two refereed conference papers based on his MEP. The supervisor expressed his concerns in supervising MEP students in WSU where most of the students lacked in academic writing skills with the exception of the first author of this paper who as a student demonstrated an excellent capability in conducting literature review, data collation, data analysis, programming and academic writing.

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Teaching and Learning Aspects of Literature Review as a Component of Doctoral Study: A Case in Western Sydney University

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Abstract: *Embarking on a three year journey of a PhD research can be a daunting task, especially when one is not entering into a pre-defined topic and when that research is in an area that one is not yet an expert in. At the beginning stage of the PhD research, advice from supervisors and peers becomes very meaningful, even small comments are helpful from fellow researchers who have experienced what one is going through. The relationship with, direction and advice from the supervisors and professionals in the field that one comes in contact with, at conferences for example, are very important for developing a professional understanding of one's topic area. Meetings and discussions with the supervisors and industry partners, networking with others in one's field at this stage is crucial to complete an effective literature review.*

The results of the literature review include a deep and encompassing understanding of one's topic, familiarity with experts in the field and with the work they have done. One also gains an understanding of the state of knowledge and, importantly, discovers the current research gaps. The process of looking for research gaps enhances one's critical analysis of the literature. Moreover the review process helps put the topic into perspective, locates it within the broader field of research, and helps one appreciate the potential benefits that the current research could offer to humanity. The literature review stage of a PhD candidature is unique. One has time to read and review numerous papers and this is a time when supervisors generally provide important input for developing the student's knowledge base. The supervisors are often busy with more advanced tasks and will probably not have the time to do such extensive perusing of all the literature to sieve out the important new developments. In this way the PhD student becomes a great assistant to their supervisors by bringing to their attention to the highlights of important new developments in their field. While the supervisor with experience can direct the candidate, as to whether or not the developments are really new, relevant and valid in light of the doctoral research topic.

The literature review is thus a very important beginning to a PhD. It builds confidence in the trainee expert, and is the first step in becoming a true expert in the field. Few will spend as much time on one topic; quite possibly one will never spend as much again. It is a unique opportunity within one's career that should be exercised with the upmost care and diligence. The first author in his own candidature found that other people's reviews in his doctoral topic area were helpful. As long as a research areas continue to develop systematic reviews of the new developments and scoping reviews of new research arenas will continue to be relevant and needed. Therefore publishing a review paper from the findings of the literature review is very beneficial and can be a great contribution to the field *and an opportunity to pass on something to help the next PhD candidates. In this regard, the first author (along with his supervisors) published a review article in a high impact journal with impact factor of 5.651, which is regarded as excellent out of his PhD literature review.*

Keywords: Literature review, scoping review, journal article, supervisor, doctoral research

1. INTRODUCTION

A PhD in Australia typically takes at least 3 years of full time research focusing on one particular topic that is innovative in nature. At the beginning this may seem like a long road ahead. It can also be a very confusing time as research topics are often not well defined at the beginning. It can feel like the description of the earth in the opening verses of The Book of Beginnings, In the beginning... the earth was without form and void (Genesis 1:2, The Holy Bible: King James Version). With effort and planning, however, things take shape. The lack of definition of the specific topic in the given field of research is actually necessary at this stage. One of the first tasks of the novice researcher is to conduct a literature review to get an understanding of the state of the art, find the research gaps and hence their project. This can also be a difficult time as one may find that one's intended topic has already been researched, gaps in the research may be difficult to find, etc. It is a time of discovery, and of understanding one's topic area. At this early stage advice from peers and guidance from supervisors is very important. Even small comments are helpful from fellow researchers who have passed the early stage, finished their Confirmation of Candidature (CoC), have defined their research topic and are now in the middle of shaping their research methodology and producing results. One feels like there is heaps of time but time moves quickly if one is not careful. One important piece of advice from a fellow researcher, was to look at review papers first as they will quickly give one an overview of the topic rather than getting bogged down in detail at first. Review papers are very useful at the beginning of PhD candidature.

The relationship with, direction and advice from the supervisors and professionals in the field that the PhD candidate comes in contact, at conferences for example, and network with are very important for developing a professional understanding of one's topic area. And the novice researcher should actively seek to engage with professionals and more experienced researchers. Thanks to his supervisor the first author was able to secure a placement with CSIRO (Commonwealth Scientific and Industrial Research Organisation) before starting his PhD and to have subsequently gained the support of an industry supervisor from there. CSIRO is one of the top research organisations in the world and so the access to experience there is most valuable. The first author also spent time in Kenya and took the trouble to engage with a Professor from Jomo Kenyatta University of Agriculture & Technology (JKUAT) in Nairobi who has helped to provide an international perspective and context to the research topic. This international contact also had an influence in guiding the literature review through suggesting research papers and giving local knowledge of design processes, current legislation and cultural-political shifts in sustainable development particular to Kenya. This paper aims to shed light on the necessary inter-relationships between students, supervisors and industrial partners for a successful literature review in a PhD study. It encourages publication at an early stage of candidature as part of developing professionalism in research.

2. LITERATURE REVIEW

Despite all the contacts, networking and good discussion there still comes the time for the novice researcher to sit down and read through the relevant literature, and acquaint themselves with the information and research documents being gathered. In today's world where there is, perhaps, an overabundance of literature it is essential to be methodical in the review process. A quick search in Google Scholar for say "rainwater harvesting" will yield one hundred and twenty thousand results, and for "flood modelling" eight hundred thousand, or one and a half million is spelled with a single "l". At this point a working relationship with a good librarian becomes valuable, as they can give advice or the library may run seminars on review techniques, search engines, using key words, Boolean searching, and much more. The State Library NSW runs a "doctrinal discovery day" designed to teach first year PhD students how to navigate their collections and online services.

There are various review methods, but it is convenient to distinguish two specific types, namely a systematic review and a scoping review. The systematic review is most relevant where a topic is more defined and a review of the current research already done on that topic is necessary. In his research the first author chose a scoping review finding it more suited to the nature of his topic and to finding new areas of research between currently mostly distinct areas. A scoping review can be defined as having five basic steps (Figure 1) and has been described by Arksey et al. (2005) and Levac et al. (2010).

Figure 1 Steps in a scoping review

Modern databases, such as Scopus, have powerful facilities that allow one to easily explore not only who a given paper references, but also who references a given paper. This is very useful when one comes across a paper that is of interesting. One quickly learns to screen papers by browsing through abstracts and choosing relevant papers to read more deeply. Papers should be categorised by keywords, for example rainwater, roof, Kenya, Australia, tank, modelling, economics, nexus, urban agriculture before being screened by title and abstract. Keeping papers in a personalised library is essential for future reference and categorisation. The first author makes extensive use of the off line Endnote software for this purpose. To find the relevant literature various search databases relevant to one's area of study should be used for example, Science Direct, Scopus, Web of Science, Google Scholar and institution repositories should also be targeted such as CSIRO's research repository, and the Food and Agricultural Organization's (FAO's) repository. Institution's repositories often have reports that are not published as journals and they allow one to focus on that particular institution's research. Once one has screened the papers one can then set down to summarising the findings, taking particular note of sections where authors encourage further studies in a particular area or note that there is a lack of research on a particular topic, as these might lead to findings and later defining one's research topic.

Writing skills are also vital in preparing a high level literature review. The ideas should be well connected, the writing should be concise yet complete so that it tells a story. Many engineering students generally have poor technical writing skills, which may prevent them producing a good literature review. This issue is elaborated in Rahman et al. (2016).

3. PUBLICATION BASED ON LITERATURE REVIEW

In order to publish, the novice researcher must climb a steep learning curve. As a first year PhD student one is most likely already learning new skills in the areas of teaching/tutoring and professional presentation, and now to put together a good journal paper one needs to become a typesetter, a proof reader, and a journalist of sorts and perhaps even a graphic designer to present their results in a clear and appealing way. One needs to be able to understand the mind of one's reader or critic and be able to satisfy peer reviewers. Publishing a review paper from a PhD literature review is not an easy task, but it is worth aiming at if for no other reason than that it makes one complete the review in a professional manner and helps one prepare one for subsequent publication. Review papers are typically longer, than original articles, for example up to 12,000 words rather than 8,000 words and journals may require a methods section which explains one's literature selection process.

There is help of course and the first thing to do is to decide on a target journal that suits the area of research and then read their author information pack. Elsevier has a general publication called "How to publish in scholarly journals" (Elsevier 2015) that covers a wide variety of journals. They also provide specific information packs for each journal, e.g. Elsevier's 'Journal Of Cleaner Production' author information pack (Elsevier 2018). These are highly valuable. Review papers are expected to be of high quality as they present no original work they are expected to be extensive and contain an in-depth analysis of the state-of-the-art and to identify areas for future research. This matches the intent of the literature review in a PhD, namely to find and define one's research questions which are then to be examined as part of the Confirmation of Candidature.

Some journals only publish original research, but many good journals publish review papers. If one starts their research perusing review papers they can easily take note of journals that do. The Journal of Cleaner Production states that they prefer a systematic review, however it is still possible to publish a scoping review paper in this journal as it is justifiable given the lack of research done on the specific topic. In the authors' case, they were able to publish a paper with a title beginning "A scoping review of..." (Amos et al. 2018). The article went through a number of reviewers, and three courses of review and revisions and finally most reviewers gave it a good report. However, at a late stage one reviewer gave it a "bad report" and so it came down to an editorial decision, which required addressing the editor personally and putting forward the case for publication. Finally the article was accepted. One reviewer made very constructive but tough comments to address, which eventually improved the quality of the final paper. For successful publication the correct guidance and support from supervisors with experience is a great benefit especially when it comes to learning the correct etiquette for communicating with editorial boards, which was the case for the first author and his Principal Supervisor (the second author). It should be noted that the first author and his supervisors also published a literature review paper in journal called "Water" based on his Honours thesis literature review (Amos et al. 2016).

4. LESSONS LEARNED

Publishing a review paper is very beneficial to learning professional research skills and is also a good contribution to the field. It also increases the citations and h index of the authors as a good review paper is cited frequently. As a researcher the first author found that other reviews were an important introduction to the current state of the topic. As long as a topic area continues to move forwards there will always be new developments and so reviews of the new developments will continue to be relevant. Review papers also present a focused opportunity for the scientific community to share critical and constructive analysis of research where original papers would be more focused on presenting new results. As well as the benefits to those reading the review the whole process can also bring updated knowledge to supervisors and industry partners. The review process is essential to one's own professional development and in gaining:

- A deep and encompassing understanding of one's topic.
- Familiarity with experts in the field and the work they have done.
- An understanding of the state of knowledge.
- Finding the all-important research gaps and developing one's research questions.
- Critical analysis of research enhanced by the search for research gaps.
- Put the topic into perspective and relate it to other relevant topics, particularly in a scoping review.
- Helps one to see the potential impact of one's research topic.

The literature review stage of a PhD candidature is in many ways is a unique time. One has time to read and review a lot of papers and this is time that few supervisors will have personally as they generally deals with many students and research projects. The supervisor is often very busy and will not have the time to do such extensive perusing of all the literature available and sieve out the important new developments. In this way the PhD student can become a great assistant to their supervisor by bringing to his attention the highlights of important new developments in their field. While the supervisor with experience can direct the candidate, as to whether or not the developments are really new, relevant and valid.

5. SUMMARY

The literature review stage is very important in the journey of PhD study, although perhaps the most confusing stage of a PhD, particularly where a topic has not been predefined. It helps to build confidence in the trainee expert, and develop professionalism in their research. Successful publication from a literature review is partly about choosing the right topic and the right journal at the right time and also about teamwork and support one has from a good supervisor and network links with industry partners. Academic writing skills are essential in writing a review paper as one needs to compare, contrast and comment on other research papers in a way that it tells a story. The literature review is the first step in becoming an expert in one's field. Few people will spend this much time on one topic. It is quite possible that one will never get this much time to focus on a literature review in one's career again and so it is a unique opportunity that should be taken advantage of. Aiming at publication in this early stage of candidature will help bring focus and professionalism to one's research.

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Comparative Study of NI Multisim and Matlab Simulink for Simulating DC/AC Inverters in Power Electronics Education

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Abstract

Rapid evolution of power electronics and their applications in the real world, specialised courses are available in educational institutions to allow learning and understanding them from basic to advanced level. However, pure course work involves conceptual abstraction, often accompanied by large mathematical exercises and calculations. These can require substantial computation steps. To eliminate this educating problem, software simulation packages have been developed over years to help learn the behaviour of power electronic devices. Multisim and Matlab are two commonly used packages in the educational space. A comparative study has been undertaken earlier at the University of South Australia, comparing these simulation packages, however limiting the scope to only rectification devices. This paper broadens the scope to accommodate inverse rectification devices i.e. inverters, to help further investigate the packages. In this regard, key requirements that forms the base of this investigation includes simplicity in design modelling, discrepancies in simulation outputs with respect to theoretical benchmark, user friendliness of graphics interface and accessibility within educational workspace. Every simulation package has its strengths and weaknesses. It is essential to investigate the features, capabilities and attributes comprehensively at a user experience level. This helps to open avenues for further development to keep up with advancing learning needs.

Keywords: Power Electronics, Simulation, Engineering Education, Inverters, Matlab, Simulink, Multisim.

1. INTRODUCTION

1.1. Background

Inverse rectifiers, also known as inverters, convert direct current (DC) to alternating current (AC) and were first introduced in the 1900s. They are based on the principle of rectification, which is AC to DC conversion (Owen 1996).

DC made its debut in late 1800s, making it the most efficient form of current. Nine years later, AC was born, and claimed to be the most dominant current at the time. AC provided easy and versatile voltage level manipulation (increase or decrease) by transformers. Breakthrough in voltage level and capacities of transmission using AC made it the standard method during the 20th century, but this was not for long. Advanced control technologies in conventional power system, high-voltage DC transmissions (which allowed minimal losses as oppose to AC transmission), and the introduction of a whole new era of renewable power generation, reinstated the need for DC (Wang et al. 2013).

DC/AC inverters are very important in this new age of power (electricity) generation. Their application spreads across a wide spectrum from domestic housing to commercial industries, and as well in modern electric vehicles today. With the linear growth of power generation, using renewable methods, one of the predominant application of inverters is in solar photo-voltaic (PV) panels. Power is generated and stored as DC in storages i.e. batteries. However most of our day to day appliances operate with AC, including general purpose outlets (GPOs) at homes. Therefore, to make this conversion happen, (DC to AC) inverters are used.

To understand and learn power electronics i.e. inverters in this case, software simulation packages have been developed over the years to help students learn the behaviour of power electronic devices. These software packages help accelerate learning and understanding power electronics in a widespread of applications in various energy conversion, automation and renewable energy systems. Not only do they help academically, but they also benefit in industrial research. These packages combine real-time experiments with virtual simulations (Khader & Abu-aisheh 2011).

1.2. Research Description

This paper investigated two commonly used simulation packages used in the academic environment for engineering students studying Power Electronics & Drives. The investigation was performed at a user experience level in the form of a comparative study review. These packages are Matlab Simulink and National Instruments (NI) Multisim.

Comparative studies have been performed in the past investigating these two packages relative to one another, in the area of power electronics courses. However, those studies emphasised findings on general power electronic devices in rectification as performed by Rao et al (Rao & Prakash 2018) and Khader et al (2011). This study focused solely on inverters. Both these software programs can carry out simulations using any electronic circuitry for any device and show its behaviour interactively to the user.

The study encompasses the following main comparison factors: Modelling simplicity; Visual simplicity; User-friendliness; Output discrepancies with theoretical calculations and Accessibility & Cost within Educational workspace.

1.3. Research Motivation

With rapid development of power electronics devices (inverters in this case) and their applications, inventing and innovating ways in learning and teaching is pivotal. Dahiya et al. (2011) stressed on how important the growth of human resources in knowledge is, to develop the economy of any nation. An important way to support this development is to complement learning and teaching techniques with computer aided simulation tools.

Simulations tools help to model, analyse and solve real world problems of complex systems in designing and enhancing technical interest. This in-turn allows flexibility and motivation to students especially in engineering education, in a cost effective and time saving manner, eliminating the need for hardware integration. Not only do they help academically, but they also benefit in industrial research for professional practice across various disciplines (Dahiya & Nehra 2011; Kashif & Saqib 2008). These tools help to accelerate learning and understanding a widespread of application in various energy conversion, automation and renewable energy systems in the engineering field, by combining real-time experiments with virtual simulations (Khader & Abu-aisheh 2011).

1.4. Scope

This paper provides an insight into theoretical literature of inverters, the simulation packages, followed by methodology of how this study was performed, results from the practical investigation by simulation, and discussion comparison analysis between the packages. The research assisted in the development of Pulse Width Modulated (PWM) inverter topology models for this comparative study, specific to Single-Phase models.

The topology models were as follows: Single Phase Half Bridge Inverter with Purely Resistive (R) Load; Single Phase Half Bridge Inverter with Combined Resistive-Inductive (LR_ Load; Single Phase Full Bridge Inverter with Purely Resistive (R) Load; Single Phase Full Bridge Inverter with Combined Resistive-Inductive (LR) Load.
A set of DC input parameters were tested within suitable range as follows: DC Source Voltage with set fundamental frequency; Suitable resistor (R), inductor (L) and capacitor (C) load values

The following outputs were recorded and analysed: Peak Output Voltage – Vo; Root Mean Square (RMS) Output Voltage at fundamental – Vrms; Peak Output Current – Io ; and Root Mean Square (RMS) Output Current at fundamental – Irms

Theoretical calculations were performed prior to simulations with the aid of Matlab coding which applied equations sourced primarily from academic coursework of Power Electronics and Drives [EEET 3016] at University of South Australia. These calculations provided an ideal benchmark of output results, which helped compare against the simulation output results from Matlab Simulink and NI Multisim.

Practical investigation involved constructing the inverter models using both software packages and simulating them with the selected inputs to observe the outputs. During this investigation, the main comparison factors outlined in the project description were analysed carefully and discussed. All results and findings of this study that are beneficial were also contributed towards coursework content enhancement of Power Electronics and Drives.

2. LITERATURE

2.1. History of Inverters

Inverters were first originated by David Prince in 1925, when he published an article on them. Rectification is the process of converting alternate current (AC) to direct current (DC). Devices which performed rectification were called rectifiers. Derived from this concept but performing the inverse conversion from DC to AC, introduced inverse rectification, and their respective devices performing this operation called inverters. Prince explains inverters to be able to invert any DC to AC irrespective of the number of phases. He explains the meaning of inverted as 'upside down', which was relative to the function or operation of the rectification in an inverter, whilst keeping the device and circuit orientation unchanged (Owen 1996).

As decades passed, subsequent developments took place with Monocyclic and Polycyclic inverters in the mid-1900s. Series and parallel inverters followed by various applications in high-frequency induction heating, refrigeration and in DC electric power distributions (Owen 1996).

The performance of an inverter is dependent upon the rectifier device used in it. Due to the limitations in rectifiers available during the early days, the full potential of inverters was not apprehended until the last decade with the heavy booming of solar photovoltaic (PV) systems and the evolution of electric vehicles (EVs). Three driving factors of the advancements of inverter technology include costs, efficiency and losses, and reliability. These factors pushed the development of power electronics rapidly which contributed more and more to the improvements of inverter technology over multiple generations and will continue to do so over the future generation of inverters (Mallwitz & Engel 2010).

2.2. Pulse Width Modulated (PWM) inverters

As Chapman (1999) describes, Pulse Width Modulation (PWM) is the process of modifying the width of the pulses in a pulse train which is directly proportional to a small control signal. This modulation technique allows to produce AC output voltage with varying voltage and frequencies, from a fixed DC input voltage in inverter application. DC input and AC output voltages can be either fixed or variable (Rashid 2004).

Inverters that use PWM control signals to produce output, are called PWM inverters. These inverters can be broadly classified into single phase and three phase inverters. They make use of controlled switching (on/off) devices like transistors and thyristors. The most commonly used controlled switching device used in PWM controllers are Insulated-Gate Bipolar Transistors (IGBTs) and Gate-Turn-off Thyristors.

Single-phase and three-phase PWM inverters can be categorized into the following topology circuits: Single-phase half-bridge; Single-phase full-bridge; and Three-phase bridge.

These inverters consist of choppers circuits. Transistors switch ON and switch OFF in turns for short time intervals at a time. These transistors undergo various switching states, creating a waveform of both positive and negative voltages from a DC input voltage to produce an AC output voltage.
Due to the utilization of switching devices, the output produced from inverters contain harmonics and can be affected by the following performance parameters: Harmonic Factor (HF); Total Harmonic Distortion (THD); Distortion Factor (DF); and Lowest Order Harmonic (LOH) (Rashid 2004).

2.3. Present status of Matlab Simulink and NI Multisim in Power Electronics Education

One of the biggest challenges faced when designing a software package for education is to achieve simplicity in design, processing of the simulated electronic circuits without undermining user friendly graphic interface. Some of these software packages include but are not limited to Matlab Simulink, PSIM, Simplorer, Pspice, NI Multisim, and PLECS etc. Over the past decade, power electronics circuits have found vast applications in Energy Conversions Systems, Industrial Automation, Mechatronics, renewable and transport sector. This was due to the swift development of switching devices and control techniques of power electronics. This enforced the need for developing programs with a certain degree of simplicity, user friendliness which would aid both educational and research purposes (Khader & Abu-aisheh 2011; Rao & Prakash 2018).

MATLAB Simulink

Matlab Simulink is very commonly used within the academic environment. Simulink provides many provisions to users with its in-built blocks, toolboxes which help analysing circuits. Some of these blocks that help in the simulation of power electronic circuits include Fast Fourier Transform (FFT) block, mean value block, Root Mean Square (RMS) value block, measurement blocks, scope and display blocks. Users can define and program models to simulate complex design and visualise the output in various forms. In-built toolboxes such as the Power System Blockset (PSB) toolbox features various electrical models of semiconductors and many commonly used power devices i.e. machines, transformers, power lines, voltage sources etc. These allow simulation of power electronics and electric drive systems i.e. bidirectional controllers and rectifier circuits as seen in figures 4 and 5 (Kashif & Saqib 2008; Zhao & Wang 2005).

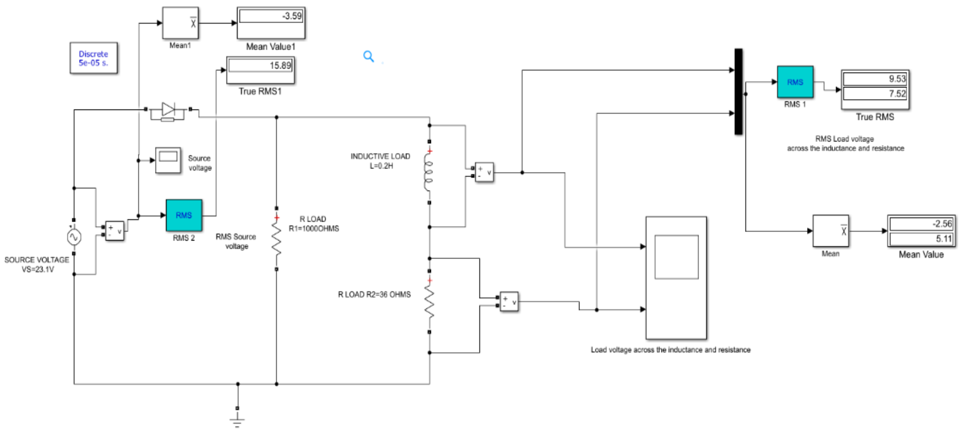

Figure 1: Simulink model of a Single-Phase Half Wave rectifier with Resistive and Inductive Load (Rao & Prakash 2018)

NI Multisim

Multisim was initially made with the intention to allow users to observe and analyse before the realization of hardware. Eventually it was deemed very useful in the educational workspace which was heavily accepted by students as Cheng describes (2011). Dynamic simulation model of the software's simulation kit is convenient, intuitive and flexible, making the simulation process quick, efficient. With a large database of configurable power electronic components, devices and test observation tools, circuits can be directly simulated. Multisim also provides a preview to the actual project related for students by providing comprehensive understanding through simulation. This ultimately stimulates the student's practical and self-exploration ability in power electronics (Cheng 2011).

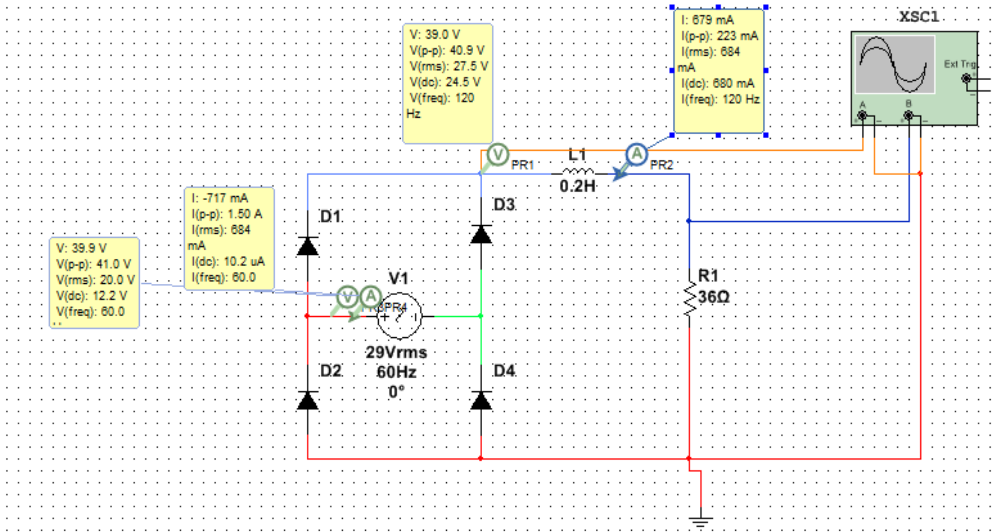

Figure 2: Multisim model of a Single-Phase Full Wave rectifier with Resistive and Inductive Load (Rao & Prakash 2018).

2.4. Research question

This paper investigates which simulation package, between NI Multisim & Matlab Simulink, is better for studying and teaching the behaviour of DC/AC inverters, in terms of modelling and visual simplicity, user-friendliness, discrepancy with respect to theory and accessibility within educational workspace?

3. METHODOLOGY

The following steps provide an outline of how the investigation in this comparative study was carried out:

- **Step 1:** Theoretical calculations using a suitable set of input parameters (DC input source voltage, resistance, inductance, and fundamental frequency) to calculate the outputs as per scope.
- **Step 2:** Construction of topology model 1 - Single-Phase Half-Bridge inverter circuit with a purely resistive load, in Matlab Simulink, setting load values to the selected input parameters from step 1.
- **Step 3:** Set voltage of the DC input source - Vs (2 split DC sources – Vs/2 each), as per selected in step 1.
- **Step 4:** Devise a switching technique set with selected fundamental frequency to switch the transistors, and duty cycle to 50% if required by the program.
- **Step 5:** Place voltage and current measurement blocks/meters in the model to observe the outputs, and scopes to observe output waveform. Record the output values and waveforms.
- **Step 6:** Construct the circuit in Multisim by performing steps 2 to 5.
- **Step 7:** Record the theoretical output results with the simulated output results, compare to determine the variation range with respect to theoretical benchmark.
- **Step 8:** Perform steps 2 – 7 for the remainder topology models, ensuring all load values set correctly as per selected in step 1.
- **Step 9:** While conducting study, observe, analyse and take note of the complexity of model construction, time consumed in both programs for modelling and simulation from a user-level, and accessibility in terms of costs and availability, for both the programs to students.

4. SIMULATION AND RESULTS

4.1. Models

A total of 8 models were constructed and simulated (4 models in each software package). In this paper, only model 4 circuit - Single Phase Full Bridge Inverter with Combined Resistive-Inductive Load is illustrated in figures 3 and 4.

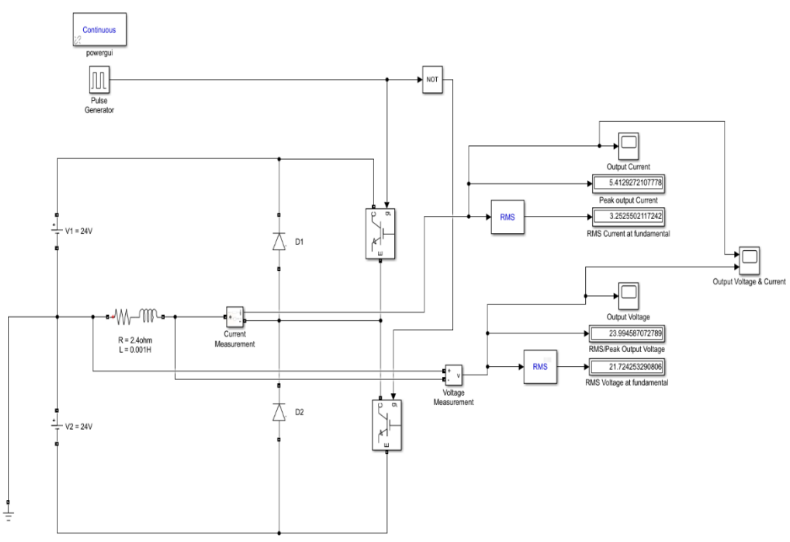

Figure 3: Simulink model of a Single-Phase Full Wave Inverter with Resistive and Inductive Load (Output blocks showing voltage and current outputs) (Kamal 2018).

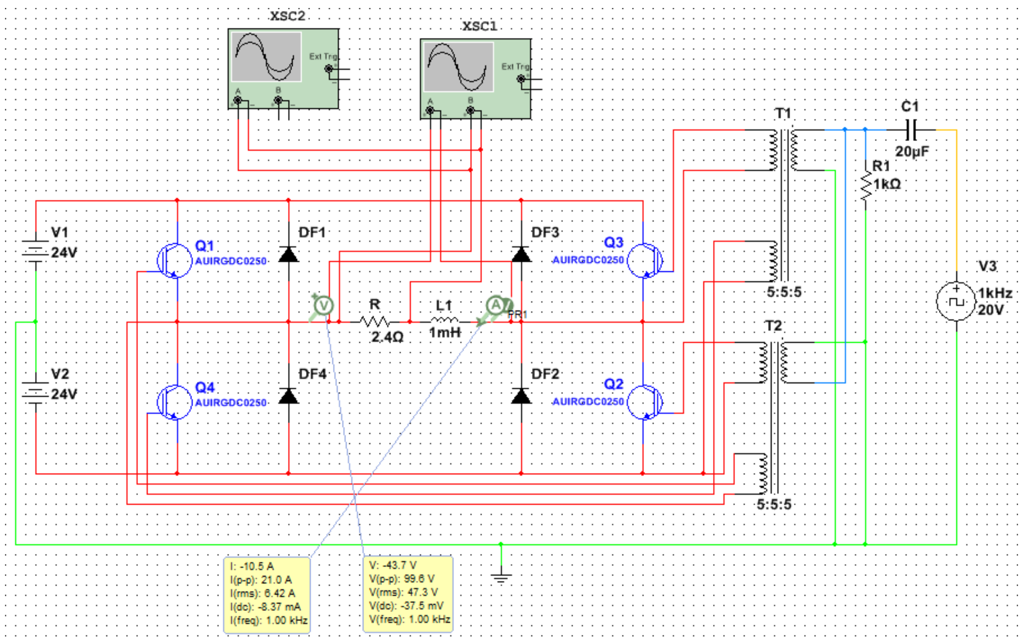

Figure 4: Multisim model of a Single-Phase Full Wave Inverter with Resistive and Inductive Load (Output blocks showing voltage and current outputs) (Kamal 2018).

4.2. Output Waveforms

After simulating the circuit models on both the softwares, voltage and current output waveforms were extracted and recorded. The waveforms for the full bridge models from figures 3 and 4 are illustrated in figures 5 - 8.

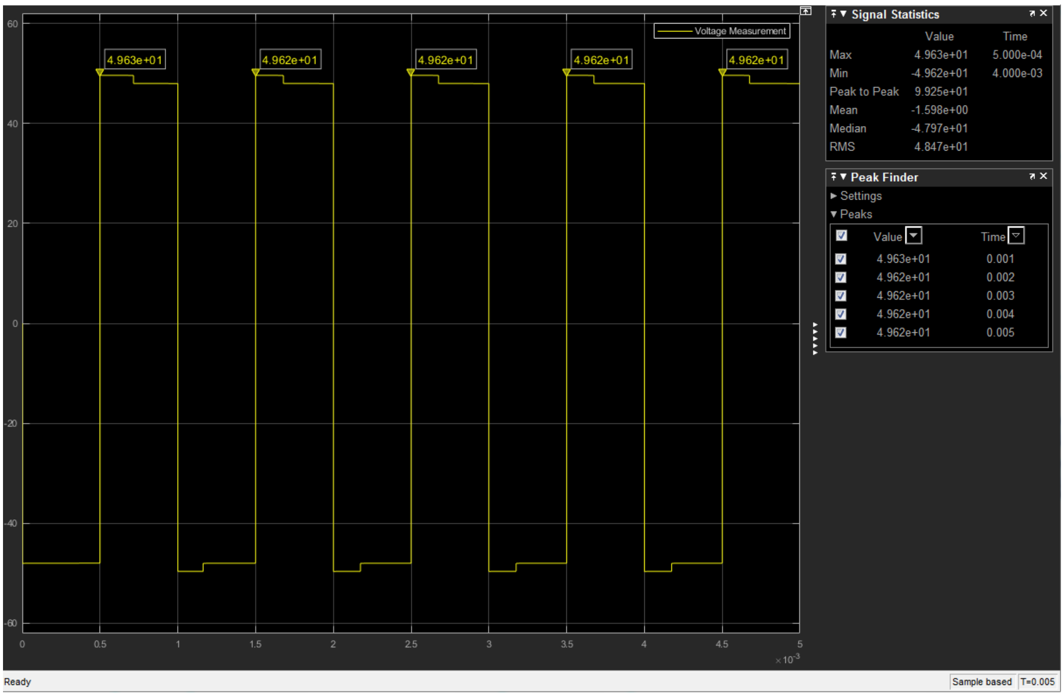

Figure 5: Full Bridge (LR load) Output Voltage waveform – Simulink (Kamal 2018).

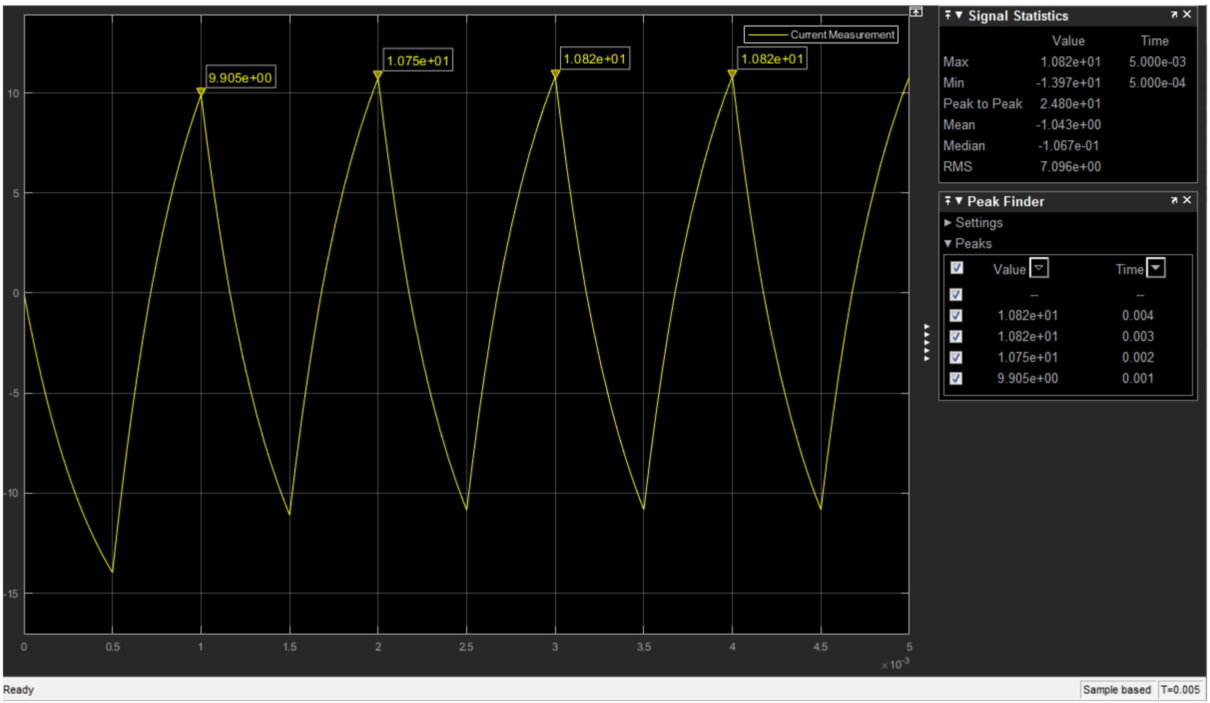

Figure 6: Full Bridge (LR load) Output Current waveform – Simulink (Kamal 2018).

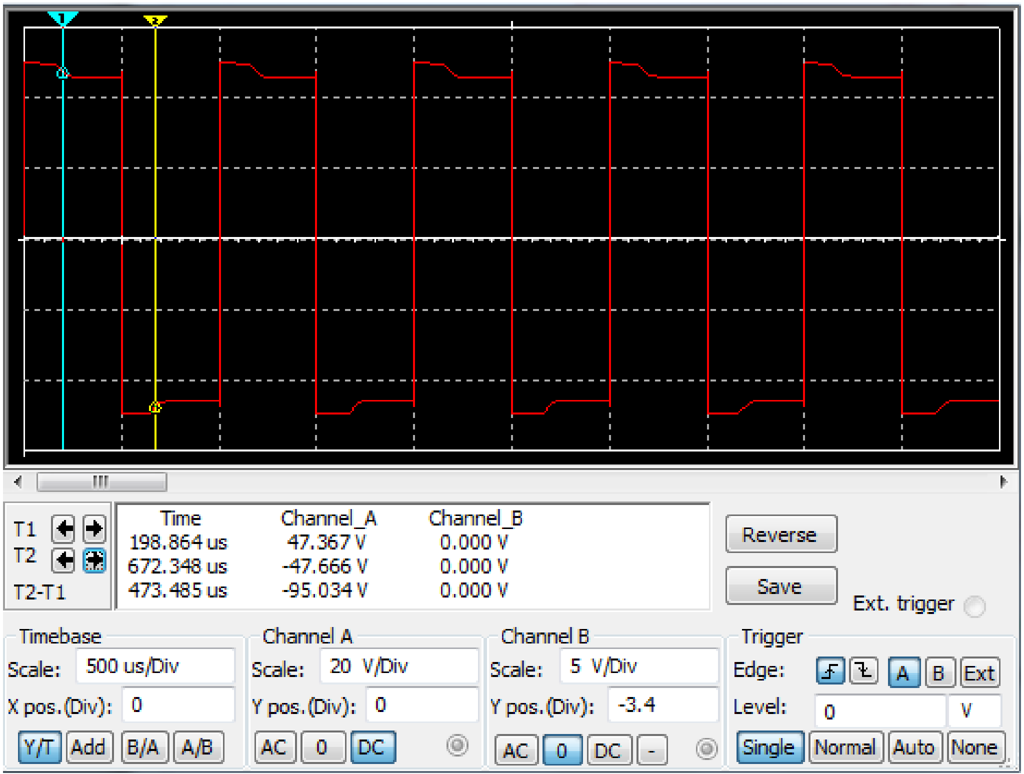

Figure 7: Full Bridge (LR load) Output Voltage waveform – Multisim (Kamal 2018).

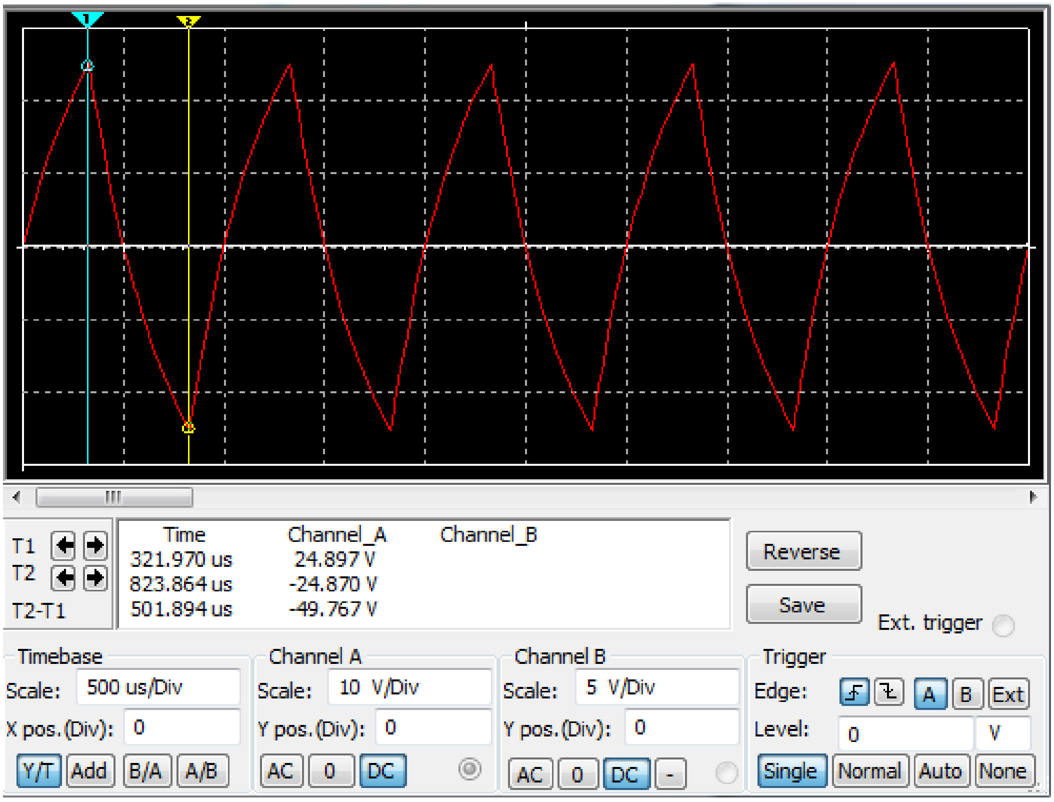

Figure 8: Full Bridge (LR load) Output Current waveform – Multisim (Kamal 2018).

4.3. Output Results

Collating all theoretical calculated results and simulation output results (from both software) of the output parameters as per research scope, a summary of results was tabulated as follows for every model. This allowed to analyse the discrepancies of the outputs clearly with respect to the theoretical benchmark.

Table 1: Summary of Results – Half Bridge (R load) model (Kamal 2018).

Variables	**Theoretical**	**Matlab Simulink**	**NI Multisim**
Vo (peak) - V	24	23.99	22.9
Vrms (fundamental) - V	21.608	21.529	20.6172
Io (peak) - A	10	9.996	9.54
Irms (fundamental) - A	9.0032	8.97	8.591

Table 2: Summary of Results – Half Bridge (LR load) model (Kamal 2018).

Variables	**Theoretical**	**Matlab Simulink**	**NI Multisim**
Vo (peak) - V	24	23.995	23.6
Vrms (fundamental) - V	21.606	21.724	21.248
Io (peak) - A	5.371	5.413	5.208
Irms (fundamental) - A	3.213	3.252	3.172

Table 3: Summary of Results – Full Bridge (R load) model (Kamal 2018).

Variables	Theoretical	Matlab Simulink	NI Multisim
Vo (peak) - V	48	47.96	45.3
Vrms (fundamental) - V	43.215	43.061	40.78
Io (peak) - A	20	19.983	18.9
Irms (fundamental) - A	18.006	17.942	16.99

Table 4: Summary of Results – Full Bridge (LR load) model (Kamal 2018).

Variables	Theoretical	Matlab Simulink	NI Multisim
Vo (peak) - V	48	47.978	47.3
Vrms (fundamental) - V	43.212	43.446	42.585
Io (peak) - A	10.741	10.825	10.374
Irms (fundamental) - A	6.425	6.505	6.331

Theoretical calculations provide indicative result figures, whereby the device is assumed to operate under ideal conditions without any control factors. Devices operating in real-world scenario are affected by various control factors, therefore will produce outputs that will vary from theoretical figures.

5. DISCUSSION

Table 5 discusses the observations and analysis performed during step 9 of the methodology, with respect to the main comparison factors outlined in the project scope description, considering the implications and limitations of simulation packages.

Table 5 Comparison between Matlab Simulink and NI Multisim (Kamal 2018).

Factor	Matlab Simulink	NI Multisim
Design Modelling (modelling and visual simplicity)	• Large library browser of components, blocks and equipment, giving the program the ability to construct circuits of anything and everything. • Availability of large variety of usable functional blocks tailored to technical areas areas extends beyond to areas such as aerospace, communications, computer systems, neural network to even basic arithmetic and many more. • Ample flexibility in making adjustments to internal parameters for all components, equipments and measurement blocks. • Exceptional visual experience with high quality waveforms from scopes. Waveforms are properly represented with accurate axis values representing current & voltage. Added features of viewing wave characteristics i.e. signal statistics, peak finder, cursor measurements etc. which are quite handy. • Simulations lack the capability of continuous run-time for a real-time output, therefore was set to a limited time adequate for acceptable results as expected.	• Stemming from its originated roots, is more geared towards the area of power electronics only. • Library database of components and equipment consist of generic/virtual items and a large range of manufacturer specific items • Blocks possess sufficient flexibility in adjusting internal parameters. • Measurements are performed and extracted using voltage and current probes which can be added while simulation is running unlike Simulink. • Automatic generation of display blocks as part of probes eliminates implementation of additional display blocks. • Oscilloscopes provide satisfactory visual representation of output waveforms but lack characteristic wave features apart from cursor measurements. • Waveforms aren’t represented with proper axis values thus necessitating manual readings based on volts/division scales. • Simulation can be run continuously for real-time output over time or set to a time limit if required.
User-friendliness	• Although intuitive of use, it requires a reasonable familiarization period. • The vast library browser, numerous sections and domains of blocks which may integrate poorly if blocks aren’t of the same domain can at times make constructing circuit models time consuming and complicated. • As the program is very popular there is plenty of informative assistance available both online and through its own internal directories.	• Due to its greater level of specialization and reduced domains, makes circuit model construction more straightforward. • The problem of block integration is no longer an issue although at the expense of versatility. • Like Simulink, this also has significant assistance available online and internally.

Discrepancy range from theoretical benchmark	• Produced output results that are closer to ideal benchmark	• Produced outputs which were further varied from ideal benchmark, closer to real-life scenario. • Originating from hardware realization background, results produced expected to be closer to real-life outputs where devices don't operate under ideal conditions.
Accessibility & Costs	• Known to be very commonly used and available in most academic institutions including host institution of this study - University of South Australia. • Easily available to be downloaded to student's personal computers via institution's software inventory. • Two educational licenses available, listed with pricing as follows: **Perpetual license** - $725AU which allows indefinite use of this package. **Annual license** - $362AU which allows the software to be used fixed period (Au.mathworks.com 2018)	• Limited availability in host institution. • Available for personal computer on special request only, which isn't always promising. • Selective laboratories under the engineering faculty of electrical and electronic discipline are equipped with it for students' use. • Only educational version available priced at $951AU (Sine.ni.com 2018).

6. CONCLUSION

This paper begins by expressing the background, description, motivation and research scope behind why this study took place.

The engineering education is well complemented by these simulation packages. Prior to simulating and investigating the inverter models practically, knowledge of developments of how inverters came into existence and how they function was important which was covered in the literature section. It was also worthwhile noting where these two simulation packages currently stood in the area of power electronics education and research, which was also covered in the literature section.

The methodology of investigation allowed a systematic approach by which the entire investigation was carried out, ensuring no steps were missed or skipped. The input parameters assigned ensured that all calculations and simulations were performed with consistent inputs.

Reviewing all major comparison factors that were taken into account in the scope of this study, both these packages do a reasonably well job in different areas of power electronics education and research, and none can be separated from the pack.

Reflecting back to the research question, there is no real winner out of the two. Matlab Simulink with its sophisticated architecture feels right at home during high level academic research. On the other hand, Multisim is more suited to a classroom environment for beginners in power electronics education.

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iCAEED GCSTMR

Challenges in Learning Urban Stormwater Modelling in Australia

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Abstract

Australian cities are facing a range of critical pressures related to urban expansion and water shortages along with the degradation of urban streams and waterways. Managing Australia's limited water resources requires an integrated and complete water cycle approach (including both quantity and quality aspects) considering "cities as water supply catchments". It is only in the past decade that significant change in urban water management in Australia has occurred. Efficient management of stormwater is essential to prevent adverse impacts on the environment by managing stormwater runoff quality using Water Sensitive Urban Design principles, while at the same time assuring reliable alternative water resources to minimise potable water demands through the concept of Integrated Water Cycle Management. Several Australian states, local and regional governments have developed technical guidelines on specific stormwater management techniques and practices. But there are no nationally consistent guidelines for ecologically sustainable management of stormwater quantity and quality. Consistent approaches to planning across local governments is important. To support efficient and effective implementation of these new guidelines an easy-to-use software-based tool needs to be developed that would provide the ability to simulate all three urban water cycle service networks (water supply, stormwater, wastewater), ranging in scale from a single allotment up to large clusters or subdivisions. This tool must model both water quantity and quality, with options for economically and technically efficient system optimisation. This paper presents a brief review of stormwater modelling practice in Australia and how stormwater modelling is taught in Australian universities.

Keywords: Stormwater modelling, WSUD, SWMM, hydrology

1. INTRODUCTION

Stormwater is water from rain, snowmelt, or melting ice that flows across the land surface as runoff. During an event of rainfall in vegetative landscape, the majority of the rainfall may be subject to infiltration and evapo-transpiration. As the urban area gets developed, the natural vegetation and pervious areas are gradually replaced by impervious surfaces (roads, concrete and buildings) which do not allow water to be infiltrated into ground and runoff volume increases. Hence, the natural movement of water changes dramatically with progressive changes in urbanization. In urban planning, stormwater management plays a significant role both in terms of infrastructure cost and sustainability of the environment such as drainage system design and maintenance.

Stormwater drainage in Australia evolved from combined sewers that rapidly discharged the accumulated rubbish, sewage, sullage and stormwater from streets to waterways (Armstrong, 1967; Lloyd et al., 1992). The impacts on waterways and amenity of urban settlements drove the separation of sewage and stormwater infrastructure. Filling of swamps and development of contributing catchments to accommodate population growth resulted in frequent flooding of early settlements. Drainage solutions emerged to avoid stagnant water, local flooding and health impacts in urban areas. Nation building works programs during economic depressions (for example in 1890's and 1920's) and following wars provided large scale drainage infrastructure throughout Australia.

Traditionally, the prime objective of urban stormwater management had been flood mitigation and the aim had always been to transport the stormwater as rapidly as possible from our urban areas to the nearest waterways. In a typical urbanised area up to ninety percent of the rainfall may flow into the hard stormwater system and produce extremely poor-quality runoff to receiving water body. To protect our environment and country's unique ecosystems, we need an approach that recognises the environmental impacts of urbanisations, the linkages between land and water management and the importance of community values and involvement.

2. WATER SENSITIVE URBAN DESIGN

The necessity to deal with both the quantity and quality of runoff has been recognised in the mid 1990's to include protection of waterways and mitigation of urban stormwater quality. The traditional stormwater management strategy is being modified by the application of Water Sensitive Urban Design (WSUD) in Australia. Broadly equivalent terms used as Sustainable Drainage Systems (SuDS) in the United Kingdom, Low-Impact Development (LID) used in Canada and the United States. The main objectives of WSUD include protection of natural systems, integration of stormwater treatment into the landscape, protection of water quality, reduction of run-off and peak flows, and addition of value while minimising development costs. The process includes treating urban stormwater to a water quality enabling reuse and/or discharge to surface waters and using stormwater to maximise visual and recreational amenity in the urban landscape (Rahman et al., 2008).

Structural and non-structural stormwater management measures often need to be combined to manage the hydrology of urban runoff and to remove stormwater pollutants. One group of stormwater management measures that has proved effective in removing stormwater pollutants associated with fine particulates (such as suspended solids, nutrients and toxicants) is constructed wetlands and ponds. Constructed wetlands also satisfy urban design objectives, providing passive recreational and landscape value, wildlife habitat and flood control. A gross pollutant trap is another structural pollution control measure that traps litter and sediment to improve water quality in receiving waters. Community involvement in clean-up programs and source controls, re-vegetation programs of disturbed land, and minimal bare soil in urban gardens (especially those on sloping land) are some of the non-structural measures.

A comprehensive review of stormwater quality in urban catchments was undertaken by Duncan (1999) and this review forms the basis for the default values of event mean concentrations for TSS, TP and TN. More recently, Fletcher et al. (2004) has updated the values provided in Duncan (1999) and specifically provides guidance on appropriate land type breakdown. Note that TN is generally consistent across each urban land use as TN is dominated by atmospheric deposition.

The following sub-sections present how stormwater system is designed in Australia.

2.1. Stormwater Quality Treatment Nodes

Following the determination of the site's water quality objectives the user (if required) needs to develop an appropriate treatment train for the proposed development site depending on site constraints and opportunities.

2.1.1 Wetland

Constructed wetland systems consist of an inlet zone (sediment basin to remove coarse sediments), a macrophyte zone (a shallow heavily vegetated area to remove fine particulates and allow uptake of soluble pollutants) and a high flow bypass channel (to protect the macrophyte zone).

2.1.2 Pond

Artificial ponds form part of a flood detention system. Aquatic vegetation plays an important role for the water quality in artificial ponds in respect of maintaining and regulating the oxygen and nutrient levels.

2.1.3 Sedimentation Basin

Sediment basins are used to retain coarse sediments from runoff. They operate by reducing flow velocities and encouraging sediments to settle out of the water column.

2.1.4 Infiltration Basin

Infiltration measures are highly dependent on local soil characteristics and are best suited to sandy and sandy clay soils with deep groundwater. This allows adequate filtration of stormwater through the soil before reaching the groundwater body. Any infiltration strategy will require an appropriate site and soil evaluation study.

2.1.5 Gross Pollutant Trap

GPTs typically remove rubbish and coarse sediment from stormwater runoff. Some GPTs also have features to trap hydrocarbons. These devices can be very effective at removal of solids conveyed within stormwater which are typically larger than 5mm in size.

2.1.6 Buffer

Buffer or filter strips, in the context of urban stormwater, are grassed or vegetated areas over which stormwater runoff from adjoining impervious catchments traverses enroute to the stormwater drainage system or receiving environment. Buffer strips are intended to provide discontinuity between impervious surfaces and the drainage system.

2.1.7 Bio-Retention

Bioretention systems (also known as biofiltration trenches) are a combination of vegetation and filter substrate that provides treatment of stormwater through filtration, extended detention and some biological uptake.

2.1.8 Swale

Vegetated swales are open vegetated channels that can be used as an alternative stormwater conveyance system to conventional kerb and channel along roads and associated underground pipe. The interaction of surface flows with the vegetation in a swale facilitates an even distribution and slowing of flows thus encouraging particulate pollutant settlement. Swales can be incorporated into streetscape designs and can add to the aesthetic character of an area.

2.1.9 Rainwater Tank

Rainwater tanks can reduce the harm to our waterways caused by too much stormwater as noted by Amos et al. (2018). Tank water can be used to flush toilets, wash clothes, water gardens and wash cars, significantly reducing demand on drinking water (Eroksuz and Rahman, 2010).

2.1.10 Generic Node

This node allows the user to simulate the treatment performance of devices not listed within the default parameters. This use of this device is similar to the processes identified for a Gross Pollutant Trap with the exception of a Flow transfer function to replicate any flow attenuation produced by the proposed device.

3. URBAN DRAINAGE COMPUTER MODELS

The design methods for urban drainage systems include a wide range from rule-of-thumb methods to computer models. The Statistical Rational method has been commonly used in Australia for computing flows for urban drainage design. Urban hydrologic models have two major components: runoff generation and runoff routing. The runoff generation component is responsible for partitioning rainfall into surface runoff and losses, while the runoff routing component routes the surface runoff from the catchment to the outlet. Runoff from an urban drainage catchment consists of an initial runoff from impervious areas (such as roofs, buildings, roads and parking lots), which flows into the storm drainage system. There is also a delayed response accompanying infiltration and storage, which occurs in pervious areas that are flat or gently sloping such as gardens, parks or playgrounds. The pervious and impervious surfaces in an urban catchment can be expected to behave quite differently, both in terms of rainfall losses and travel lag-times.

Hydraulic and hydrological modelling are essential tools for investigating how networks operate, for planning and designing improvements to water infrastructure systems and for predicting water cycle processes. Well-constructed and calibrated hydraulic and hydrological models can clearly demonstrate the consequences of fluctuating and increased water demands, pipe flows and pressures in water and wastewater systems, the impact of climate change on the distribution and quality of water resources, above and below land surfaces, and on infrastructure by forecasting water pressures and flows, deficiencies and risks, and lay bare the effectiveness of proposed solutions. Both hydraulic and hydrological analyses create opportunities for improved operational performance and cost savings.

As reported in Aitken (1975), there had been many attempts to use overseas computer models directly or to modify overseas models to suit Australian urban catchments. At that time, two problems were found in selecting overseas computer models for use in Australia. The first problem was the existence of separate systems for urban stormwater and sewage water collection in Australia as opposed to single systems used in these models. The second problem was the soil types underlying the urban areas in different cities in Australia (with high variations in infiltration characteristics), which were different to those that were used in the development of the overseas models. However, these problems are not issues anymore since most overseas drainage models are flexible enough to cater for the above two problems. In some cases, the overseas computer programs are successfully modified to suit the Australian conditions

While several models are available to simulate precipitation-runoff processes, some of the commonly used models (in Australia) include Run-Off Routing Burroughs (RORB), Storm Water Management Model (SWMM), Stormwater Runoff Model (STORM), Runoff Analysis and Flow Training Simulation (RAFTS), Stormwater Drainage System design and analysis program (DRAINS), Model for Urban Stormwater Improvement Conceptualisation (MUSIC), Hydrological Engineering Centre - Hydrological Modelling System (HEC-HMS), Storm Water Management Model (SWMM) and

Hydrologic Engineering Center's (CEIWR-HEC) River Analysis System (HEC-RAS). Table 1 shows different software models and their common uses in the industry.

Table 1: Different stormwater software Models used in Australia

Model	Stands for	Used for
RORB	Run-Off Routing Burroughs	Used to calculate flood hydrographs from rainfall and other channel inputs. It can also be used to design retarding basins and to route floods through channel networks.
SWMM	Storm Water Management Model	All aspects of the urban hydrologic and quality cycles are simulated, including surface runoff, transport through the drainage network, storage and treatment
STORM	Stormwater Runoff Model	Computations of treatment, storage and overflow proceed in an hourly basis by simple runoff volume and pollutant mass balance for the entire catchment. Since this model runs on hourly time step, this model is not suitable for small catchments where time of concentration is less than one hour.
RAFTS	Runoff Analysis and Flow Training Simulation	Suitable for modelling of catchments ranging from rural to fully urbanised. The model is capable of analysing catchments comprising natural waterways, formalised channels, pipes, retarding and retention basins, and any combination of these. There are no specific limitations on the catchment size.
DRAINS	Stormwater Drainage System design and analysis program	The DRAINS program will perform hydraulic grade line analyses, design stormwater drainage systems and produce summary graphs and tables, and pipe long section drawings.
MUSIC	Model for Urban *Stormwater* Improvement Conceptualisation	By simulating the performance of stormwater quality improvement measures, music determines if proposed systems can meet specified water quality objectives.
HEC-RAS	Hydrologic Engineering Center's (CEIWR-HEC) River Analysis System	Designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels. Widely used in Australia for flood profile calculations. In urban drainage context, HEC-RAS can be used to design and analyse of trunk drainage systems.

MUSIC model is used to model a stormwater treatment train in a small development to prove to council that the development will not result in excessive pollution in a waterway. SWMM model might be used to model an entire development to prove to council that it will not cause excessive stormwater discharge to waterways or surrounding properties. RAFTS focuses on stormwater hydrology including soil infiltration. It can be used for a much quicker 1D model only – but could be a good starting point. Generally speaking, MUSIC is the simpler and, hence, cheaper model to run, followed by RAFTS. But MUSIC has its own limitations – little observed stormwater quantity and quality data are available at urban catchments to calibrate the MUSIC model, there is little observed water data to verify the model outcomes and data obtained for one region are being used in other regions without adjusting to local conditions (Imteaz et al., 2013).SWMM model can provide a significant amount of data, to the point of fully modelling one's entire stormwater system but is often more expensive to set up and run. STORM is a continuous simulation model. This model is basically a planning model and therefore, not suitable for detailed quantity or quality modelling. DRAINS provide a Windows graphical interface. Design rainfall patterns can be entered separately. Results such as runoff hydrographs are displayed graphically and can be pasted into other Windows programs such as spread sheets and word processors. It performs hydraulic grade line analyses, design stormwater drainage systems and produce summary graphs and tables, and simple pipe long section drawings. HEC-RAS is a computer program for modelling water flowing through systems of open channels and computing water surface profiles. HEC-RAS finds particular commercial application in floodplain management and flood insurance studies to evaluate floodway encroachments. The main drawback of using RORB for urban catchments is the lumping of all impervious areas in a sub catchment without considering directly connected and supplementary areas separately and it does not model the pipe hydraulics.

There are too many models to select from and hence, an easy-to-use software-based tool needs to be developed that would provide the ability to simulate all three urban water cycle service networks (water supply, stormwater, wastewater), ranging in scale from a single allotment up to large clusters or subdivisions. This tool must model both water quantity and water quality, with options for economically and technically efficient system optimisation.

4. CIVIL ENGINEERING COURSES IN AUSTRALIAN UNIVERSITIES

Now we can have look for undergraduate civil engineering coursework for water related knowledge, thus we can get an idea before entering in the real industry what our engineers are learning to apply their knowledge regarding urban stormwater management in Australia. Generally, all universities cover three major topics related to water management, which include fluid mechanics, hydrology and hydraulics, as described below.

4.1 Fluid Mechanics

This subject aims to enable students to understand key concepts and fundamental principles, together with the assumptions made in their development, pertaining to fluid behaviour, both in static and flowing conditions; deal effectively with practical engineering situations, including the analysis and design of engineering systems and devices involving fluids and flow; appreciate possible applications and links to other disciplines; and engage in further specialised study or research. The subject also aims to enhance interests in fluid phenomena and applications. Learning of fluid mechanics is challenging as explained in Rahman (2017a).

4.2 Hydrology

This course provides the basic skills to carry out the hydrologic analyses and designs that are often encountered in engineering practice. Knowledge of engineering hydrology is required for the design of stormwater drainage systems, for the management of flooding and is also needed to determine how much water can be reliably obtained from water supply catchments and groundwater systems. The course provides a background to hydrological techniques used by professional engineers, including those codified in 'Australian Rainfall and Runoff-A Guide to Flood Estimation'. Students will undertake a range of hydrological analyses and computations using spreadsheets.

4.3 Hydraulics

The emphasis of this course is the application of hydraulic theory to the solution of problems commonly encountered in engineering hydraulics and to the design of hydraulic systems and structures. The basic concepts of the conservation of mass, momentum and energy are reviewed, extended and applied to a variety of hydraulic systems. New material on unsteady pipeline and open channel flows, loose boundary hydraulics and coastal hydraulics is presented and applied. Students are practiced in the design and analysis of open channel, pipeline and pumping systems and a wide range of hydraulic structures. In Table 2 we can have a quick look of different Australian universities with course work component related to water management.

Table 2: Different Australian University's Undergraduate Courses (Water Management) of Civil Engineering Degree

<table>
<tr><th>University Name</th><th>Courses offered related to water management for civil engineering undergraduate program</th><th>Component of the course</th></tr>
<tr><td>UNIVERSITY OF NEW SOUTH WALES (UNSW)</td><td>CVEN2501 Principles of Water Eng'g OR EQUIVALENT
ENGG2500 Fluid Mechanics for Engineers
CVEN3501 Water Resources Engineering</td><td rowspan="5">Fluid Mechanics
Basic control volume equations, Basic governing differential equations, Dimensional analysis and similitude Ideal fluid flow, Boundary layers, Flow in pipes, Pipe networks
Hydrology
Hydrologic cycle, Precipitation and intensity-frequency-duration analysis, Evapotranspiration, Infiltration, Runoff, Energy, mass and momentum equations in open channel hydraulics, Characterisation of steady flow, Channel controls, Channel design, Flood frequency analysis, Unsteady flow, Reservoir routing, Rainfall runoff routing.
Hydraulics
Open channel hydraulics – types of flow (e.g. steady, uniform), friction equations, rapidly-varied flow, continuity, energy and momentum conservation, gradually varied flow, water surface profiles, software packages, hydraulic structures (channel appurtenances, culverts, bridge waterways)</td></tr>
<tr><td>UNIVERSITY OF SOUTHERN QUEENSLAND(USQ)</td><td>ENV2103 Hydraulics I
ENV3104 Hydraulics II
ENV3105 Hydrology</td></tr>
<tr><td>UNIVERSITY OF NEWCASTLE (UON)</td><td>CIVL2310 Fluid Mechanics
CIVL4330 Hydrology
CIVL4450 Water Engineering</td></tr>
<tr><td>UNIVERSITY OF TECHNOLOGY SYDNEY (UTS)</td><td>48641 Fluid Mechanics
48362 Hydraulics and Hydrology</td></tr>
<tr><td>WESTERN SYDNEY UNIVERSITY (WSU)</td><td>300762.2 Fluid Mechanics
300765.2 Hydraulics
300766.2 Hydrology</td></tr>
</table>

From above component details of three major subjects studied in undergraduate of civil engineering we understand that students should learn fundamental application of water engineering. But as we are approaching towards water sensitive urban design, we understand that it is not only about hydrology and hydraulics, it is now related with microbiology and chemistry as well. Students are not clearly getting focus on implementation of urban stormwater management towards water sensitive modelling until they do specific course or research-based study on this area. Engineering education need to be evolved in ways that improve the readiness of graduates to meet the challenges of the twenty- first century geared towards sustainable development.

5. CHALLENGES IN STORMWATER MANAGEMENT

As we are approaching Integrated Water Cycle Management (IWCM) era, which offers stormwater reuse, generally for non-potable purposes security for water supply, improvements to water quality in waterways and urban amenity. This reduces the demand on the potable water supply of the urbanised area considers ‘cities as water supply catchments’.

There is still lack of sufficient data for capturing and reusing stormwater. Rather than using different software models for hydrology, hydraulics and water quality, an easy software tool needs to be developed which would be easily accessible with all updated data and have friendly user interface for scientist, students and industry engineers.

Undergraduate students in civil engineering should be able to recognise the environmental impacts of urbanisations, the linkages between land and water management and the importance of community values and involvement after finishing their study. In today’s social context, in which a considerable number of contrasting signs reveal that our society is currently contributing to the planet’s collapse, “a new kind of engineer is needed, an engineer who is fully aware of what is going on in society and who has the skills to deal with societal aspects of technologies”. The social aspects of hydrology are discussed by Rahman (2017b) where it is noted that many water projects fail due to poor consideration of social and ecological issues. The advanced skills in hydrology need to be learned by the students to master the uncertainty and risk involved with hydrologic modelling to achieve sustainable water cycle management (Rahman et al., 2018).

6. CONCLUSION

Several state, local, and regional governments have developed technical guidelines on specific stormwater management techniques and practices. Consistent approaches to planning across local governments is important. The guidelines should outline why we need to manage our stormwater in ecologically sustainable and integrated ways. In order to facilitate the integrated planning process, authorities need to ensure that relevant codes, policies and guidelines relating to stormwater management and reflect environmental values and water quality objectives for local waterways, so that water quality as an issue is properly addressed when land use is proposed to be developed. It has been found that there is lack of consistent urban stormwater design approaches and design data in Australia. The university courses on water management are still focusing too much on mathematical aspects, which need to be upgraded to cover social and sustainability aspects to a greater depth.

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Evaluation of 40 Credit Points Thesis in Bachelor of Engineering Course in Western Sydney University, Australia

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Abstract

Engineering bachelor degree course generally consists of a final year major project/ thesis in a four-year study. In many universities, this is undertaken as a design project, either by a single or group of student(s). Many engineering schools have an embedded honours component where the project/thesis is integrated in the final year of study. In contrast, university science course is typically of three-year duration, followed by an additional year of honours study by the academically outperforming students. To enhance honours program, the former College of Health and Science, Western Sydney University (WSU) in Australia undertook a major benchmarking exercise of its honours programs in 2009. The author as the then School of Engineering Honours Coordinator compared honours courses in a number of major engineering schools in Australia and made wider consultation with relevant WSU academics and committees to make a submission to the honours benchmarking committee. The outcome of this exercise resulted in the implementation of an engineering honours program in WSU comprising of a thesis component worth 40 credit points. In this paper, the author, as the School Honours Coordinator and as supervisor of honours students presents his coordination, supervision and learning experiences of engineering honours thesis at WSU. It has been found that the 40 credit points honours thesis in WSU enhanced the learning outcomes of the students, which was demonstrated by the students' increased recognition in the state competitions, HDR enrolments and peer-reviewed publications.

Keywords: Honours, thesis, WSU, final year project, engineering course, learning

1. INTRODUCTION

Engineers shoulder the responsibility of building a 'better world to live in" using the natural and human resources in an environmentally and economically sustainable manner, although environment has been a major focus only during the last few decades. Engineering courses place a notable emphasis on mathematics and physics as these courses utilise the fundamental mathematical and physical principles to solve a real problem for end-users (Rahman et al., 2018a). Science and engineering arguably differ in their focus as engineering attempts to adapt scientific principles to solve a given problem under many practical constraints and engineering solution may be far from ideal.

Delivery of engineering courses have been well-researched covering aspects such as application of blended learning and project-based approaches to fluid mechanics (e.g., Alam et al., 2007; Rahman, 2017), social hydrology (Rahman, 2018) and science subjects in engineering (Rahman et al., 2018b). However, there is little research on final year honours thesis/projects in engineering. Engineering bachelor degree courses in Australian universities are of four years duration with the final year containing a design project or an honours thesis. The design project is often undertaken by a group of students. Often, the design projects are assigned to the students who are performing below the credit-average level. A student performing at least at credit-average level, generally undertakes a mini-research project often called honours thesis, and this student is regarded as honours student. However, at many engineering schools in the world, honours degrees are awarded based on a student's overall mark in their four years' of study. For example, a student achieving a grade point of average (GPA) of at least 3.75 out of 4 is awarded BEng (Honours) and a student with GPA smaller than 3.75 receives BEng.

When BEng graduates compete for a Higher Degree Research (HDR) scholarship with science honours graduates, it is often perceived that science graduates are better prepared to succeed in HDR compared with BEng or BEng (Honours) graduates. The author took the leading role in benchmarking the engineering honours degrees at WSU in 2009 under a project, formed by the then Executive Dean of the College of Health and Science, called "Positioning CHS Honours for Growth: An evaluation of Honours in the College of Health and Science, UWS", led by Professor Merlin Crossley. This paper presents the benchmarking process of engineering honours program as a part of this project, issues related to the management of honours courses at the School of Engineering, WSU for five years by the author and his experiences in honours supervision.

2. OVERVIEW OF ENGINEERING HONOURS PROGRAM AT WSU

The engineering course at WSU started in early 1990s, since then there had been a number of major changes into the engineering courses. The author took a leading role as Course Coordinator of Civil Engineering course in upgrading engineering courses during 2004-2005. In this upgrade, first year engineering was made common to six engineering disciplines (civil, electrical, environmental, telecommunication, computer, robotics & mechatronics). A major change was the introduction of four free electives, which allowed a student to take any units in WSU. The argument was that this will offer a greater flexibility to a student's unit selection and will reduce resource requirements from the school and moreover it will enhance the knowledge base of an engineering graduate. However, the introduction of four free electives forced abandonment of number of important units such as chemistry, traffic engineering and application of geographical information system (GIS) to engineering and statistical methods in engineering.

It was noticed that a good number of students selected 'soft units' as their free electives. Another observation was made that a large number of students had been selecting electives from construction management course, which resulted in 100% increase in the student numbers in a number of units causing resource problem in construction management discipline in WSU.

3. EVOLUTION OF 40 CREDIT POINT HONOURS THESIS IN WSU

Before 2004, all the final year BEng students had to undertake individually Major Investigation Report (MIR) 1 and MIR 2 (each worth 10 credit points), where MIR 1 focused on problem identification and critical literature review and MIR 2 focused on data analysis and interpretation of results. A major advantage of this approach was that individual student had to carry out his/her own research in completing Mir 1 and MIR 2. A major disadvantage was the honours students (who were receiving 65% or higher marks) were doing similar projects as a non-honours BEng student. Furthermore, due to smaller number of tenure academics, many academics had to supervise 10 or more students in a semester. In changing the project/honors component, the following key changes were made: (i) A student receiving 65% average mark in their 2nd and 3rd year studies, should be given a chance to undertake honours where Engineering Thesis unit will be worth 40 credit points (i.e. 50% load of a full year study) spreading over two semesters; (ii) Engineering thesis will be assessed by two independent examiners, one nominated by the supervisor of the honours student and the other by the School Honours Coordinator in consultation with the Head of School and School Research Committee; (iii) Engineering project (worth 20 credit points) to be undertaken by a group consisting of three to four students.

Academics were eager in taking up honours students but less willing to take project groups. The demand for honours supervision was too high that led the School Research Committee to formulate a stringent guideline to allocate honours students to willing academic supervisors. The rationale of allocating honours students was "the best GPA achieving student to be assigned to the best performing academic". To identify the best performing academic in research, a metric was developed by the School Honours Coordinator in consultation with the Head of School and School Research Committee where points were allocated for journal papers (measuring quality by the A*, A, B and C rating of ERA 2010) and research incomes by the academic supervisors. This resulted in key researchers in the School getting the best honours students, some of the students did not like the allocated supervisor and topics. In one occasion, the best GPA achieving student was allocated to a research area/supervisor which was disliked by the student. Interestingly, this very student wrote an exceptionally high quality thesis and was eventually highly satisfied with his supervisor and overall outcome. This perhaps proved the efficacy of the honours academic and students' allocation guidelines. However, after about two years, student's choice was accounted for and School Honours Coordinator discussed the topics allocation with the student and supervisor to make both the parties happy.

A problem was encountered where the less research active academics were missed out in getting any honours student to supervise, and that led allocation of final year project students to these academics. This created dissatisfaction among the academics. As a result, the guidelines were revised where academic supervisors and honours topics were allocated solely based on the preferences by the honours students. Here, the higher GPA achieving student received his/her first preferred supervisor/topic, followed by the 2nd highest GPA achiever, and so on. This made both the academic supervisors and students happy.

4. CONTENT OF UNIT 300675 HONOURS THESIS

The unit 300675 Engineering Thesis was a 40-credit point unit, which was coordinated by the author for five years (during 2008-2012). The main learning outcome of the unit was to equip students with the ability of carrying out research with minimum supervision. It was expected students completing this unit should be able to complete minor research project relatively independently, write refereed papers and undertake further research studies at postgraduate level. The unit contained four assessment components: (i) writing a research proposal of about 1000 words, due in week 4; (ii) literature review due in week 12; (ii) an abstract of about 300 words due in week 18; (iii) a 15-minute oral presentation plus 5 minutes questioning in the School honours conference, due in week 20; (iv) a thesis about 10,000 words, due in week 26. The thesis carried 100% mark while the other components had a satisfactory/unsatisfactory grade. The extension for submission of final thesis was only approved in exceptional circumstances.

The appointment of examiners was made in confidence and the two independent examiners were not allowed to communicate with each other. The unit had only four face-to-face lectures covering (i) unit rules, assessment tasks and honours grading; (ii) conducting a critical literature review including efficient library search; (iii) essentials of writing a good thesis; and (iv) beyond the honours thesis. The unit outlines and all other relevant materials were placed in online (vUWS). The unit required self-learning by students with little assistance by unit coordinator and weekly meetings with the supervisory panel. It was expected that at least 50% of the theses in a given year should lead peer reviewed publications.

5. BENCHMARKING OF HONOURS THESIS IN WSU

The Executive Dean of the former College of Health and Science formed a high level committee in 2009 consisting of recently retired senior academics of other engineering schools and senior academics of the then School of Engineering in WSU, headed by Professor Merlin Crossley. As

School Honours Coordinator, the author assisted the bench marking exercise of engineering honours thesis. In the review by the Committee, it was noted that the top 20% of WSU engineering theses were of 'excellent quality' that often led to refereed publications. This bench marking outcome provided a level of confidence to the WSU engineering honours program. The quality of WSU engineering honours theses were further demonstrated by the wining of the 'best undergraduate engineering thesis' award in the state of New South Wales (NSW) on many occasions. This award is given to the best thesis among all the undergraduate engineering theses completed in a calendar year in the six NSW universities. For example, two students supervised by the author received the best thesis award in NSW (by the Engineers Australia, Sydney Division); another two students received the best thesis in water area by Australian Water Association, NSW Branch. A number of similar awards were received by WSU honours graduates supervised by other academics as well.

The criteria for Honours grade determination in engineering were similar to other honours courses in WSU such as science and arts. For example, honours grade was awarded solely based on the mark of honours thesis, i.e. a student getting at least 85% in the honours thesis was awarded Honours 1. This created a number of issues such as a student having GPA of about 5 could get Honours 1 if he wrote an exceptionally good quality thesis. In contrast, a student having GPA of 6 (out of 7), but receiving a lower mark (e.g. 83%) in the honours thesis would miss Hons 1.

This created dissatisfaction among many honours students and their supervisors, which prompted a submission by the School of Engineering asking a new Honours grading system similar to many other engineering schools in Australia. The author took a major role in making the case where a comparison was made on the grading of honours graduates among major engineering schools in Australia (i.e. University of New South Wales, The University of Sydney, Monash University and The University of Melbourne). The WSU Academic Senate was pleased with evidences and new honours grading method was approved for the then School of Engineering. The typical distribution of honours students in WSU is provided in Table 1.

Table 1: Typical yearly enrolment in engineering honours program in WSU (year 2011 data)

Discipline	No. of students	No. of students receiving Hons 1	No. of students receiving Hons 2 Div I	No. of students receiving Hons 2 Div II	No. students receiving Hons Div III
Civil and environmental engineering	8	2	6	0	0
Electrical Telecommunication and computer engineering	10	1	6	3	0
Robotics and Mechatronic engineering	5	2	2	1	0
Total	23	5 (22%)	14 (61%)	4 (17%)	0

6. RECENT CHANGES IN HONOURS THESIS IN WSU

In a recent course restructuring, the thesis units in Bachelor of Engineering (Honours) program in WSU has been reduced to 20 credit points; however, there are 20 credit points on projects as well. In this case, every student has to carry out two thesis units (10 credit points each) and a 20 credit point group projects. Also, all the engineering students in WSU will get an honours degree if they successfully complete the course irrespective of the mark they receive. This is in contrary to engineering degrees in most of the other countries.

7. HONOURS THESIS SUPERVISION EXPERIENCES BY THE AUTHOR

The student feedbacks on unit (SFU) reports of Engineering Thesis generally had been very positive. Many honours students reported this as the best unit in their study as it integrated their learnings in the previous three years and provided an opportunity to apply their knowledge learnt in other subjects to solve a problem or carry out an independent research. Some students felt that two much emphasis was given on writing in marking the final thesis. Engineers Australia rated Honours Thesis as an excellent unit with high standards being maintained. The quality of theses was regarded excellent generally, with some exceptionally high quality theses.

Almost all the previous WSU engineering honours students secured a job within six months of graduation or received scholarship to carry out PhD study. Some of the honours students secured jobs in reputed engineering companies. In few cases, employers contacted the author to recruit a given honours student, and in few instances, there were competitions among employers to recruit certain student. In few instances, senior academics from other elite universities intended to recruit WSU’s top honours students. In most cases, the honours students preferred to work in the industry instead of starting a HDR degree straightaway.

The author supervised 26 honours students in WSU, 11 of these students got High Distinction/First Class Honours (42%) and another 12 students got Distinction (D) (representing 46% students), i.e. a total of 88% students got either HD or D, which is an excellent outcome. These data show that the adopted honours student supervision strategy by the author has produced an excellent outcome. Six of these honours students undertook PhD with the author as their principal supervisor. A number of high impact journal articles were published based on honours theses supervised by the author, these papers have received over 350 citations in Google Scholar (two have citations of 132 and 129) (e.g., Eroksuz and Rahman, 2010; Rahman et al., 2012; Brash and Rahman, 2017).

8. CONCLUSION

This paper presents the evolution of 40-credit point BEng honours thesis in WSU. This unit/subject presented 50% of the full time workload in a year-long study. Students who completed this 40 credit points thesis demonstrated a high level of skills in carrying out research, which allowed them to have a smoother transition from undergraduate to doctoral study. The author presented his experience in supervising honours students in WSU. It has been found that the 40-credit point thesis was a clever move by the Engineering Team at WSU. However, the introduction of this thesis plus another 40 credit points free electives led to the cancellation of a number technically important units/subjects, which has not been seen positively by many academics that triggered a course restructuring where Honours thesis has been reduced to 20 credit points.

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Doctoral Supervision: A Case Study in Western Sydney University, Australia

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Abstract

Doctoral study is the highest level of study where the best academically performing students carry out specified research under an expert supervisory panel in a university. The role of a doctoral supervisor is to train a student having little/no experience in research (novice) so that the student becomes an independent researcher at the end of his candidature. The paper presents the author's experiences in supervising doctoral students in Western Sydney University during the last seven years. The author highlights the common difficulties faced by the doctoral students. It has been noted that the doctoral students face significant difficulty in literature review, research writing and statistical analysis in the field of statistical hydrology (author's area of expertise). However, a strategic supervision can make a student successful in gaining necessary skills to publish high quality journal articles and to write an excellent thesis.

Keywords: Doctoral research, literature review, research skills, independent research

1. INTRODUCTION

Higher degree research (HDR) in Australia is generally a full research degree where a student needs to carry out two to four years' of full time study under a supervisory panel. HDR supervision often creates a close professional tie between a student and a supervisor who work together for a significant amount of time to investigate a new problem or to make a significant innovation in a given field of research. In this journey, a supervisor attempts to mould a student from 'novice' to 'master' (Bastalich, 2017). In this venture, expertise knowledge of the supervisor in the given topic area is necessary, but this is not the sole criterion of best supervision as the supervisor may need to appreciate the student's frame of mind, his/her background, culture, family situation and emotion to accelerate his/her dormant potential to achieve the best outcome.

Delamount et al. (1998) mentioned that a delicate balance must be maintained between "control" and "non-intervention" in PhD supervision. According to Lee (2008), supervision is a balance between "independence" and "dependence" of the student in carrying out the research. Hockey (1994) stated that a supervisor should understand his/her role in "establishing boundaries" about intellectual and counselling engagement with a PhD student. PhD research is often viewed as a difficult time where people oscillate between fear and excitement (Owler, 2010). In a PhD study, many students go through a level of anxiety (Wisker and Robinson, 2013). 'Hands on' approach in the supervision often leads to quicker PhD completion as compared to 'hands off' approach (Sinclair, 2004).

This paper presents the HDR supervision experience of the author who has over 10 years' of experiences in supervision in hydrology/water engineering field.

2. AUTHOR'S HDR SUPERVISION STRATEGY

The author believes that HDR supervision is a sophisticated, high-level teaching process in which research learning is central with two important objectives: timely student completion and production of high quality publications by students. To achieve these two objectives, his HDR supervision pedagogy revolves around six strategies:

I. identification of key research questions in the early period of candidature;
II. open door policy for students;
III. regular presentation by students to relevant research groups;
IV. critical but constructive feedbacks on writings in timely manner;
V. selecting target journals for publications during early candidature and
VI. early start in drafting thesis.

He adopts a 'hands on' mode at the early period of the candidature, and then a 'hands off' mode at the later period so that a student can complete his/her thesis more independently. He enables a student to network with the fellow PhD students and former PhD students, which have been very successful in enhancing student learning in relation to mastering specialist software and programming skills.

He believes that a 'personal touch' is important in HDR supervision depending on the student's personal circumstances, in particular for the international students. He serves as a role model to his HDR students by introducing his own high quality publications to his students in the early period of their candidature. He also utilizes the publication success of his former students to motivate the new HDR students. He emphasizes that if his former student "Mr x" can publish in "high-impact journal y", you will be able to do so. This confidence building and positive supervision strategy has enabled his HDR students to produce numerous high impact publications.

He believes that interaction between the HDR students and industry experts can make the doctoral research outcomes more relevant to the industry and wider community. Based on this philosophy, he connects his HDR students with the industry experts in the Sydney Water, WaterNSW, CSIRO, Bureau of Meteorology and WMA Water. This has produced some excellent outcomes in terms of contribution by his HDR students to the national guide "Australian Rainfall and Runoff" and creation of employment opportunities for his HDR graduates. He also introduces his students with world-renowned researchers in his field while attending conferences or via skype or tele-conferences.

He believes that recruitment of HDR students need a well-thought strategy to sustain a good number of HDR students over the years. In this regard he instills a passion for research among his Honours and Masters students, which has produced an excellent result. He has attracted 27 HDR students (19 PhDs and 8 Masters by Research) as Principal supervisor; eight of these students were his former Honours or Masters Coursework students. He also assists his HDR students in preparation of their admission and scholarship applications. He believes that the relationship between the HDR supervisor and a student is a life-long relationship where mentorship is critically important. Based on this principle, he supports his HDR students in finding jobs, providing leadership in conferences, and reviewing journal and conference articles.

The author believes that one of the best ways a HDR student learns is through producing peer reviewed publications, which enables a student to develop ability to present research in a concise and scholarly manner and to defend his/her ideas by addressing reviewers' comments. Based on this principle, Rahman has proactively engaged his HDR students to produce numerous scholarly publications.

3. MAJOR DIFFICULTIES FACED BY HDR STUDENTS AS EXPERIENCED BY THE AUTHOR

A PhD student faces numerous challenges in his/her candidature as it is a journey that has uncertainty in every stage, e.g., whether one will be able to complete the degree within the specified time, whether his/her thesis will be accepted, whether he/she will be able to publish high impact journal articles based on his/her PhD thesis. Some of the challenges in HDR studies are noted below. The "buzz words", which are quite common for a typical international HDR student is displayed in Figure 1.

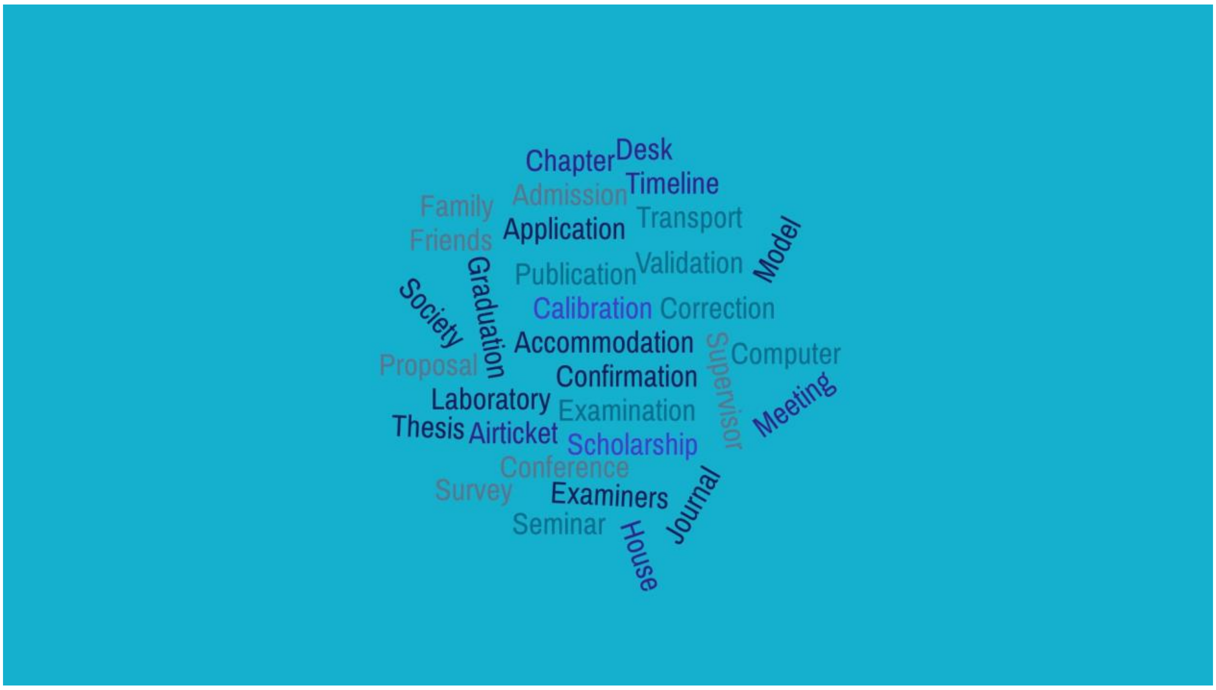

Figure 1: Common buzz words during the candidature of a typical international HDR student

Challenge 1: To understand the key concepts in the area of research. A keyword may be very well known to the supervisor, but it may not make much sense to the new students. It takes months to appreciate the meaning of some of the keywords by the students, such as homogeneity, station year approach, index approach, uncertainty bound, Monte Carlo simulation.

Challenge 2: To adjust the new environment, with fellow students, new city, new climate, and so on at the beginning for an international student.

Challenge 3: To carry out a critical literature review on the given topic area is often frustrating and seems to be an endless task as there are hundreds of papers in a topic area.

Challenge 4: To master a programing language and statistical techniques to solve a mathematical problem, often needed in the research field of the author, which is water and hydrology.

Challenge 5: To write the research proposal, paper and thesis is often challenging, particularly for international PhD students.

Challenge 6: To find a balance between PhD research, family, work and health. There are many part-time PhD students who have to work hard to earn money to support him/herself and sometimes his/her family.

4. CASE STUDY OF TWO PHD STUDENTS SUPERVISED BY THE AUTHOR

Student 1: First language – English, born in Australia, Schooling and BSc in Eng completed from Australia

This student demonstrated extraordinary success, starting from number of 'Low" grades in undergraduate study, then completing an excellent PhD and becoming a nationally reputed researcher in engineering hydrology. His strengths included high mathematical capability, programming skills, writing skills, self-determination and hard working.

Table 1: Case of an excellent PhD student

Aspect	**Comment**	**Achievement**
BEng	Poor results in earlier years, then many Ds/HDs in the 3rd and 4th years.	Published two papers from Honours thesis
MEng (Research)	Completed part-time while working full time in a consulting company.	Published two papers from Masters research.
PhD	Completed PhD with WSU scholarship plus industry top-up	Published 14 journal articles.
Post-Doctoral Research	Completed project of national significance	Developed and tested a new regional flood estimation model for Australia
Major contributions	National guideline National software	Co-authored chapter in Australian Rainfall and Runoff (ARR) – National Guide. Co-developed RFFE Software, used over 10,000 times in the last two years to design flood safe structures
Citations	Google Scholar	Citations: 876 (as on 22 Nov 2018) h-index: 16

Table 2: Case of a very good PhD student

Aspect	Comment	Achievement
BEng	Excellent results from a good overseas university.	Within top 10 in the class
PhD	Completed PhD with WSU scholarship	Published 6 high impact journal articles based on PhD thesis.
Post-Doctoral Research	Completed a project within six months	Published a journal article in a journal with impact factor close to 6.
Major contributions	National guideline	Contributed to Australian Rainfall and Runoff (ARR) – National Guide.
Citations	Google Scholar	Google Scholar citations: 162 (as on 23 Nov 2018) h-index: 7

Student 2: First language – Not English, born – overseas, Schooling and BSc in Eng from overseas

This student had a poor start and could not publish any refereed paper in his first two years of PhD candidature, but he changed his supervisory panel after about 2 years. Thereafter, he demonstrated an excellent performance, e.g. published five high impact journal articles based on his PhD thesis. His main strengths included time management, high quality literature review, and systematic data analysis and very good writing ability.

5. 6. HIGH IMPACT JOURNAL PUBLISHED BY THE AUTHOR'S PHD STUDENTS

The author motivated his PhD students to publish high impact journal articles based on their PhD theses. The main strategy was to set two to five research questions in a PhD research at the beginning of candidature, each leading to a journal article. It was noted that a working outline and timeline attached to each of the tasks worked quite well. Often, preparation of the first draft was the most difficult task. The journal selection was also important where the author always targeted a higher level journal initially with the view that if the paper is rejected the next lower level journal can be selected. The review comments were always addressed in a team environment e.g. the student and supervisor meet and discuss the comments in preparing the rebuttal. Table 3 presents a summary of the journal articles written by his students and the associated Google Scholar citations. It can be seen from Table 3 that few PhD students did very well with a high rate of publication.

In terms of thesis preparation, students who published a higher number of journal articles selected thesis by publication. Examiners preferred this type of thesis as compared to the traditional thesis.

The theses examination took two to four months' time by the examiners. It generally took about six months to complete the examination and approval process for graduation by the students. Most of the thesis required English editing by the author or professional editor.

Table 3: PhD students supervised to completions by the author as Principal Supervisor and their refereed publications

Student	Year of completion	No. of journal articles	Google Scholar citations as on 23 Nov 2018
Student 1	2012	5	76
Student 2	2013	8	204
Student 3	2013	14	876
Student 4	2014	3	38
Student 5	2015	3	112
Student 6	2015	6	162
Student 7	2015	3	107
Student 8	2017	4	54
Student 9	2018	3	48
Student 10	2018	2	42

6. CONCLUSION

PhD study needs a team effort by the student and his/her supervisor where the role of the supervisor is critical. The author of this paper supervised ten PhD students to successful completions in the last seven years. These students are employed in water industry and making significant contribution to

Australian water resources modelling and management. Two of these students authored chapters in the national guideline – Australian Rainfall and Runoff, regarded as Bible of flood hydrology. One student has outperformed in the list of students, and has become a national level expert in hydrology. The author won the WSU's VC's Excellence Award in 2015 and 2017 in Higher Degree Research Training and Supervision. The author has found PhD supervision as the most enjoyable part of his career.

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A Formative Approach to Construction Education

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Abstract

Construction educators continue to assess and refine their approach to the classroom. Most instructors know the credible models of teaching, learning, and assessment; however, not all have been applied to the construction classroom. In this paper, the researcher specifically applies the formative approach to management courses of the built environment with the specific intent of producing four general learning outcomes: a) vocabulary mastery b) concept framework understanding c) iterative problem-solving d) writing skill advancement. Each of these gives students a management skill set that is valuable to many construction firms. This formative approach is focused on the process of teaching, learning, and assessment. It does not change the content in any construction course. It emphasizes skills which are professionally valuable to both student and the industry they may work in.

Keywords: construction education, formative teaching, student learning, progressive assessment

1. INTRODUCTION

Improving industry readiness of the newly graduated is an important outcome. To accomplish, a significant part of this, it is critical to engage students in Higher Mental Processes. Modeling as many student engagement practices in and outside the classroom in what Bloom (1984) suggests. He adds that trying to replicate one-on-one tutoring effective gives the instructor a good model to consider as proven outcomes to encourage continuing the journey. Dochy and Segers (2018) assert that the "stickiness" of knowledge is dependent on impactful learning. They state that enriching her or his body of knowledge, skills, and attitudes (KSAs) so that they can confidently apply the framework to future situations.

Construction education and the graduates it produces are critical components to improving the industry. The newly graduated have been immersed in today's effective practices of leadership, management, and technology. Each one of us has out-of-date ideas, but new graduates bring up-to-date thinking to the industry. They have "fresh eyes" and want to learn to be efficient in our challenging environment. Overall, they have a positive effect on the industry.

Stephen Covey (2004) suggests, "Begin with the end in mind". Designing a course backwardly has its advantages. The benefit of determining a goal and then, plotting a detailed course to arrive there with the students is a simple idea. Daugherty (2006) asserts three steps: 1) Identify the desired results 2) Determine acceptable evidence of knowledge (assessment) and 3) Plan learning experiences, instruction, assessments to meet the requirements of steps 1 and 2. Kelting-Gibson (2005) believes that educators should keep the following question in mind: ''How do we make it more likely by our design that more students really understand what they are asked to learn?'' To accomplish this, it is suggested that the instructor take a detailed and holistic view of the educational transformation process and its components such as deeply understanding the student, course content, assessment tools, setting, self, and the desired outcome.

Ruge and McCormack (2017) state that effective student learning occurs when knowledge is integrated and overlaps. Critical considerations are interweaving professional and academic skills development; creating a closer connection between assessment and skills development; raising student confidence in learning and professional employability.

In this paper, a limited number of teaching, learning and assessment focuses are suggested by the researcher's industry interactions and classroom experience. By concentrating on a few, instructors free themselves to invest more time and effort ingraining the focuses on students' total learning experience. This paper discusses the reasoning and conclusions for recommending four general learning focuses along with a credible learning, teaching, and assessment process commonly known as the Formative Approach. Additionally, this paper attempts to address common criticisms.

This paper asserts construction education is a journey that is never static nor complete. The intent is to prompt more thinking and discussion about this important industry subject. Undergraduate education is the context for applying this paper's assertions. This paper explains the process and focuses on bringing along the knowledge and skills of the aspiring construction contracting professional.

From there, listed are the focuses believed important, in sequential order for the teaching and learning process: 1) Vocabulary Mastery 2) Conceptual Framework Understanding 3) Iterative Problem Solving 4) Writing Skill Advancement. After that, this paper describes a credible delivery method: Formative Teaching, Learning, and Assessment.

The first focus listed is "Vocabulary" starts the process. Students are immersed in construction labels and definitions. Obviously, this helps instructor and students (and eventual employers) understand each other's questions and answers. Precise language is a value among most construction executives. The last focus listed "Writing" finishes the process. A person with an emerging writing skill will grow her/his thinking and speaking performance. Looking past undergraduate education, it is no secret that writing is a core part of graduate school and for good reasons.

The four focuses and this paper's recommended delivery method accumulate. From the first focus onward, the emphasis on vocabulary continues. Accordingly, the second focus on conceptual frameworks continues onto the last course. Listed are the four and discuss the approach that binds these together – the Formative Approach.

2. THE FOUR FOCUSES

This section describes the Four Focuses – those educational content areas that provide the backbone for an industry-ready education. In this section is listed four focuses to that have high career value.

Vocabulary Mastering - vocabulary is the set of proper labels and definitions of concepts. Words and actions are all people have to interact with others; a good industry-ready vocabulary is critical for the new graduate's credibility and effectiveness. Precise vocabulary lends gravitas to the speaker. It gives her or him perceived depth of understanding. Someone with a functioning industry vocabulary can communicate with fewer misunderstandings in less time. Everyone wins.

This vocabulary focus – the use of the right word or phrase – comes only from understanding the accurate meaning of that word or phrase. To learn this is a remedial exercise – less exciting than technology improvements or risk strategies, but no less important. Words comprise the language, and without language, professionals cannot think as well nor communicate efficiently. Using precise vocabulary is less risky. Proper words form the basis of accurate conceptual frameworks, which leads to the next focus.

Understanding Conceptual Frameworks - having a "mental template" helps the construction professional filter and interpret what she/he sees and hears. That same template can help them explain their idea. The first conceptual framework suggested is that success in construction is always predicated on:

- Safe behavior
- Quality installation
- Cost adherence
- Schedule timeliness

These have obvious value. Providing these four outcomes to Construction Service Buyers makes for better business relationships. Relating every issue to the possible effects on Safety-Quality-Cost-Schedule is a great "best practice."

Sometimes, these mental templates can be visually shown. Visual artifacts are memorable and "sticky" in someone's memory. There are many journal articles and academic texts populated with graphical representations of critical concepts for construction students to understand. Concepts such as Risk-Reward, Supply-Demand, Overhead Cost Application, Unit-Based Job Cost or Target Marketing. These graphics can be the basis for quickly communicating important considerations when deciding. As everyone has heard at least once, "a picture is worth 1,000 words." There are dozens of different construction contracting concepts that can be graphically displayed and labeled. It is important to state that from the researcher's experience and reading that most construction professionals are visually attuned.

Iterative Problem Solving - "The first answer is the wrong answer," as one of my mentors says. That is, those who hurry to conclusions as if they are on a television game show are often wrong. Even if correct, they many times have not thought of their answer thoroughly so, it will not stand the test of time. Details matter in construction contracting.

Careful and often slower thinking facilitates better answers, decisions, and qualitative judgment. Any construction challenge usually possesses a complex set of dynamics. Only when one questions and re-question do professionals give themselves time to collect and analyze more information carefully. As the last step, interjecting subjective considerations helps, so conclusion(s) are holistically strong. For the Instructor, using case studies and challenging problems help show the value of iterative thinking

The researcher presents several scenarios in the classroom to emphasize this. One is a 4-mile route and an earthmover's speed to show the need to think and compute first before answering. Another is a project return on investment calculation challenge. Still, another is a quiz about the cost of rebar per ton and concrete per yard, together and separately. One of our favorites is a bridge-building exercise – a bidding and building competition. For case studies, there are construction-centric ones from publishers such as Harvard Business Review. During these exercises, the instruction to students includes that famous NASA saying, "work the problem."

The emergence of intercollegiate competitions in areas such as Design-Build and Heavy Civil have much the same effect. Each school's team is given a set of plans, specifications, and scenario with which to determine an approach. In a sequestered setting, they are left to think through the challenge with only each other. The iterations of thought are presumed to be in the dozens. This is realistic to successful problem-solving in construction. The judging panels are industry professionals who deliver the final iteration.

Iterative thinking is often slow but, the final product will stand the test of time. It is a habit to instill and nurture. The resulting thoughtfulness and detail orientation are often high. As proof, semester-long project-type learning is the norm in many elite university programs, construction or not.

Writing Skill Advancement - writing leads thinking and speaking. It prompts high mental processes. If writing is improved then, the researcher has seen an improvement in the other two. Iterative writing with feedback from a knowledgeable Instructor provides clarity. Well-expressed thinking is not as evident in the construction industry as contractors wish. This means that graduates who have clarity and organization in their writing are more valuable than other applicants.

One compelling reason for focusing on writing is that liability risk is high for construction contractors. Contemporaneous, clear, and complete writing protects contractors. Quality writing is only possible if the previous three focuses are ingrained. That is, vocabulary identifies, conceptual frameworks organize, and iteration produces complete writing.

Writers must research to generate impactful content. Whether it is delay history or re-mobilization costs on a project, these facts have to be discovered and vetted for truth before they are committed to paper. In the classroom, this research sensitivity is started by lectures citing data sources and later with challenging questions ("Can you find this answer?") on students' submittals.

Organized and articulate content earns creditability for the writer, speaker, and thinker. Words, concepts and their expression in a logical and straightforward way deliver information that can convince, persuade, instruct or protect.

Strong writing is centered on content, not formatting or rules. However, errors are always a concern. To keep mistakes low in number, an editor – (or now, software) – can help. Content is many things, such as a fact, argument, insight, connection, or explanation. When the construction professional who is trained in writing is immersed in the facts of a complex situation, clarity emerges, and a reasoned path forward can be created whether in discussions or on paper.

Everyone can learn to write competently. A strong example of writing is a loved one's eulogy. Any person who has lost someone dear can write a compelling message about the departed. The focus is high, and the deceased's essence is clear to the writer. Many times, there is no holding back of content. Due to the personal nature of such as task, the eulogy will be rewritten multiple times until it states what is intended.

3. PUTTING IT ALL TOGETHER: THE FORMATIVE PROCESS

The Formative Teaching, Learning and Assessment's goal is to constantly monitor the learning progress of the student and adjust the teacher's delivery for real-time improvement. This process delivers those features that contractors want most in graduates: It does this through iteration and immersion. The process is a continuous process throughout a semester. This is a long time to think and rethink thoroughly about the subject matter at hand. It might be considered a cycle. With this in mind, there are sub-cycles - from the introduction of a concept to the student's mastery and application of the same concept. A key step in-between is the instructor's check on understanding or misunderstanding. This real-time monitoring approach includes asking the question, "How might this class be taught better."

The formative process of learning may be longer. A Ph.D. dissertation is an example of a multisemester one. It involves a disciplined process while learning new concepts and mastering them shown through writing a lengthy document with others monitoring for quality. The Ph.D. committee typically checks the document several times a year for accuracy and completeness of thinking. In contrast, the summative process is one where the student learns and then is assessed at the end of an educational unit. Commonly, this occurs several times during a semester with quizzes and tests. Many times, without an active connection to previous topics.

The researcher has used the formative approach extensively in the classroom structured and implemented the following Formative process. As a specific example, he taught a specialty contracting course and required each student to select a trade. From that, they wrote a company operating plan. This plan included the long-term business strategy along with how the company processes of acquiring work, constructing projects, tracking the results and human resource management. Weekly lectures' containing content followed the same sequential order helping students understand the key content.

Each student would submit their expanding plan every three weeks with a first version *ungraded* but reviewed and comments given by the instructor. This "free" submittal gives the students an idea of what is expected. This is especially important in nurturing first generation college attendees, international students, and those generally possessing below average confidence.

Through iteration, students develop the vocabulary, conceptual frameworks, and writing skills necessary to succeed through immersion. Each submittal contains instructor's comments which must be answered with corrected or updated text. This is a form of immersion. With this iterative and careful review of student work while mentoring their learning process, comes the thoroughness, independence, and steadiness. Integrity arises at least partly out of the combination of these processes. The instructor's insistence of timely work perfected over four months discourages excuses. As most know, the industry dynamics reward construction firms when tasks are "done, done" on-time – if so, safety improves, quality is higher, and productivity exceeds competitors. So, an Instructor's insistence on completeness and timeliness of work transforms students' thinking to align more with the realities of our industry.

In practice, if an undergraduate construction program followed a complete formative process, its beginning courses would emphasize vocabulary, then foundational concepts such as safety, quality, cost, and schedule. Later, classes expand to cover components of each such as ergonomics (safety and long-term health), eliminating rework and workarounds (quality and planning), labor productivity (cost and quality) and scheduling (planning and risk management) in its end of program courses. Each class would have a healthy dose of continuous writing. Many times, a graphic(s) would be required to be used to explain salient points further. Her/his writing would be electronically checked for originality and on-time submittals gauge conscientiousness.

As an everyday example, if a person is passionate about Virtual Design and Construction (VDC) – mastering the four focuses helps guide their life-long learning. At the end of their formal education including outside classroom activities, writing about VDC's challenges or new developments clarifies her or his thinking about such things. To wit, they know what they think and why they think it. This is an asset in any serious discussion. Also, clarity of thought begets insights. Insights may be breakthroughs that others have never realized. This transformation of thinking is core to what construction education is about.

Quite frankly, instructors are thrilled when students "find their voice." Professors and publication editors confirm that this is a real phenomenon. The students enjoy it the most. They can confidently use a powerful tool with which to transform other's thinking. In the researcher's experience, it takes much work but is well worth it.

As an aside, if someone were to outline an online course for the construction industry, a person could use these four focuses as a starting point. The researcher has experience with facilitating these kinds of classes. There is an impersonal nature to e-courses, so the Instructor's personality and artfulness are not readily evident to the learner. However, instruction and assessment for vocabulary, conceptual frameworks, solving complex scenarios and writing progression dovetail nicely into distance learning.

Overall, whether in-classroom, online or a blended approach, the described structured process of inputs and outputs in teaching, learning and assessment appears to produce better outcomes.

4. CRITICISMS

Others will criticize some of this paper's recommendations. This is to be expected and is a healthy part of this discussion.

The Focus is on the Science of Teaching, Not the Art. Many believe teaching is more art than science. Many instructors agree. This white paper may reduce teaching to a checklist of actions (science) with no regard to the soft skills (art) required to generate student motivation and practical knowledge.

Instructor Time. This is a factor; however, with the development of electronic means of submission, reviewing, commenting, and plagiarism checking, the assessment work is easier than before. However, the researcher can attest to more time needed than a summative assessment.

Program Time. Some may say that this proposed approach adds time required to an already overwhelming set of requirements for a construction program to meet. It may be true; however, the focuses and formative approach do not add to existing curriculum nor time needed per class. With the suggestion of a writing component to each of the final program courses, this proposed model may be adding to the instructor's assessment burden.

5. CONCLUSIONS

This paper is written to prompt discussion about improving the quality of contractor desired skills of university graduates who will enter the construction industry. It is not exhaustive, nor does it pretend to contain best practices, only what the researcher has found that to be effective.

Formative teaching, learning, and assessment is an effective approach in the researcher's experience. There is much literature to confirm its value. The process facilitates many positive outcomes such as better 1) vocabulary capture 2) mental templates, 3) iterative problem solving, and 4) writing skills. More continuous writing assignments containing emerging research will improve these four.

Each year, industry professionals witness new requirements and realities. University construction education helps address industry change with its focus on industry research which updates teaching content and introducing new topics. There is no predicting the industry's future path, but in many respects, it will not follow the past. Therefore, preparing for more change possibilities with up-to-date and deeper thinking is valuable. From our perspective, seeking to make students more thoughtful and self-reliant while ethically sensitive is the answer. From these strengths, producing professionals who possess a few powerful skills and can add value to the construction industry is more certain.

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Grand Water Challenges: How do We Teach Our Students – A Case for Bangladesh and Australia

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Abstract

Water is vital source of life, indeed, if there is no water, there is no life. Access to adequate water is essential for every living being, maintaining sustainable development and ensuring healthy ecosystem. Water demand is increasing for expanding cities, industries and agricultural activities, and consequently, leading to water crisis worldwide. In most cases, either people do not care or pay less attention on the issues related to water and the processes that lead to its contamination. According to the UNESCO (Sources No 84, November 1996), the supply of fresh water will fall short to the demand by 2030 if we continue businesses as usual. It is also reported that more than one-third of the world's population are suffering from either getting access to the pure water or diseases associated with polluted water. The statistics is alarming, and related not only to polluted water but also individuals' limited knowledge regarding water contamination. Therefore, the urgency of learning about sustainable water system has been felt crucially all over the world and there is a pressing need to create awareness and educate community people ranging from primary school children to the high profile professionals about the importance of sustainable water use. The aim of this study is to present few case studies on water contamination to show the seriousness of the problem. It also presents how we can educate our engineering students to find innovative solutions to tackle global water problems. A comparison on tertiary education systems in Bangladesh and Australia has been presented to identify the differences in terms of student learning in water engineering at undergraduate levels in these two countries.

Keywords: Water, engineering education, pollutants, ecosystem, sustainability.

1. INTRODUCTION

According to the UN resolution 64/292, approved on 28 July 2010, portable water is a basic need of human beings and access to safe drinking water is individual's basic right. However, setting specific strategy to provide drinking water to all is still a challenge in many parts of the world. The issue is much more serious for developing countries, specifically those who have large population. One report shows that access to safe drinking water is directly or indirectly linked to poverty (Mazvimavi & Mmopelwa, 2006). The control and leadership over water resources are included in direct links while access to drinking water is considered indirect link. Therefore, poverty is the one of the main reasons for people not having access to improved quality water which ultimately affects their health and wellbeing.

Provision of safe water is more than just a basic need. In many rural areas, critical household productive activities upon which their livelihood depend are related to the supply of water such as watering rice fields and vegetable gardens and livestock and moulding bricks (Makoni, Manase, & Ndamba, 2004). The quality of supply water is a major issue and society must have all the information related to the quality of water that they are drinking. In some cases, water may be good for watering gardens and washing cloths but not fit for human consumption.

There are number of problems such as water stress, scarcity, access, and risk that affect the quality of life. People living in different geographic locations are facing at least one of the above issues in getting access to safe water. For example, the World Bank published a report on water quality in Bangladesh in January 2018 where they found that 80% of the household tap water is contaminated with E.Coli and the statistics is same for pond water (Joseph et al., 2018). The High Court of Bangladesh issued an order on examining the quality of supply water by the Dhaka Water Supply & Sewerage Authority (WASA) after local newspapers surfaced the World Bank report ("High Court forms committee to test quality of WASA water," 2018). A five-member committee has been formed to investigate the issue. The aim of this work is to present several case studies to understand the severity of water problems across the globe and how we are preparing our tertiary students to tackle this issue in near future. The case studies are related to arsenic and lead contaminations, water borne diseases, groundwater depletion and water stress. We have made a comparison on tertiary education systems in Australia and Bangladesh to comprehend why and how our graduate students from a developing and a developed country are being educated on water issues. A number of alternative measures are proposed that can be introduced to the education system to make the learning process more interactive and enjoyable.

2. CASE STUDY I: ARSENIC CONTAMINATION IN DRINKING WATER IN BANGLADESH

The arsenic (As) contamination in groundwater and its detrimental effect on human health is well known to the world. Hundreds of millions of people are affected and the issue becomes a global concern. In case of Bangladesh, it is believed that the extent of the arsenic problem is more severe than one may think since many of the wells are not tested and may have contained unsafe level of As. In some of parts of Bangladesh, the contamination level is about 1000 μg/L which is 20 times higher than the safe level recommended by World Health Organization (50 μg/L). Consumption of water from this sources resulted widespread diseases and death (Cao et al., 2018; Nickson et al., 1998). Efforts have been made to identify the sources of arsenic and how the element mixed with groundwater. Though the mystery about the source has been solved, there is no unified solution for decontamination process (Chowdhury et al., 2000). Moreover, the testing process is too difficult to sustain in a regular basis since the test is expensive. A picture of Arsenic contamination in different regions of Bangladesh can be seen in **Figure 1**.

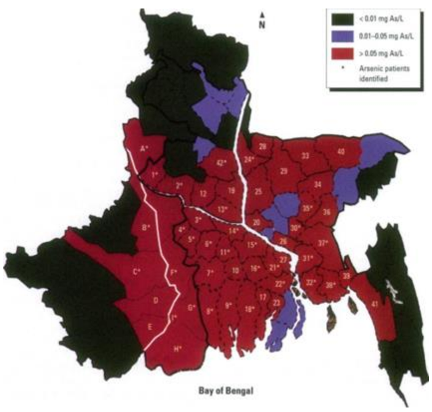

Figure 1 Arsenic contamination in Bangladesh (red areas contain arsenic above the toxic level) (Chowdhury et al., 2000).

Figure 2 shows the effects of arsenic concentration on human health related diseases. As can be seen, most of the people are vulnerable to end up with cancer when the contamination level is more than 50 μg/L for a certain period of time. Rahman et al. (2018) presented how arsenic contamination in Bangladesh is affecting the society such as family break down, isolation and mental illness (Rahman et al., 2018).

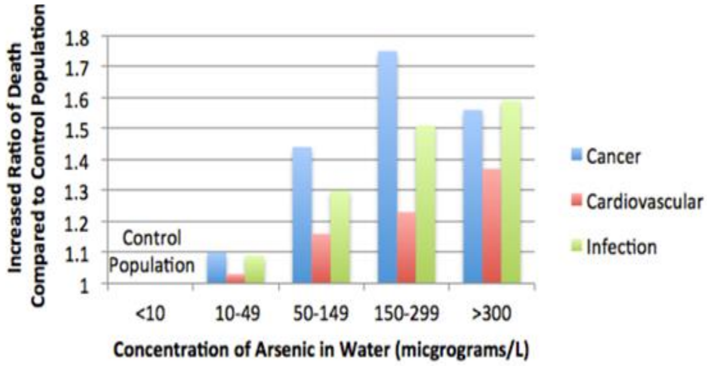

Figure 2 Arsenic poisoning induced deaths by cause (Dalin et al., 2017).

3. CASE STUDY II: WATER BORNE DISEASE IN NGAMILAND DISTRICT IN NORTH WESTERN BOTSWANA

Haron (2017) reported that 95% of Botswana's population has access to the safe water supply which are chemically treated and purified for human consumption. However, it is also reported that rural communities are still collecting their drinking water from open untreated sources which pause severe health risks. The gazette settlements are controlled and monitor by government which looks after most of the services including water supply. The counterpart, ungazetted settlements, is responsible for individual household to get most of the services. This situation has resulted in an outbreak of water-borne diseases in the area called Ngamiland district situated in the northern part of the country where most of the settlements are ungazetted. The community uses nearby open surface water source coming from Okavango Delta and its associated tributaries. **Figure 3** shows the use of surface/river water for domestic purposes by the communities.

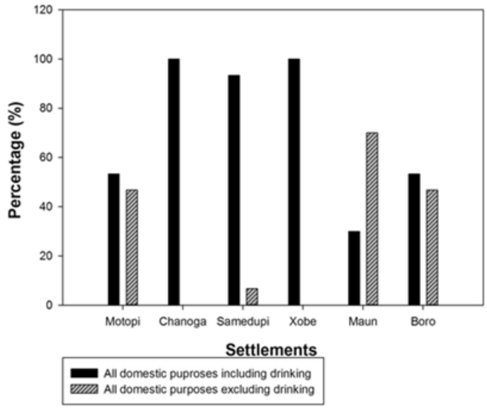

Figure 3 Boro-Thamalakane-Boteti river water used by different communities for domestic purposes (Tubatsi, Bonyongo, & Gondwe, 2015).

As can be seen, almost everyone is using surface water for their daily needs. However, the water of Boro-Thamalakane-Boteti river system is contaminated with physicochemical and microbiological parameters such as turbidity, E. coli, and fecal streptococci which have detrimental effect on human health. According to the Botswana Bureau of Standards (Tubatsi et al., 2015), the concentrations of these contaminants have exceeded the set limits for drinking. **Figure 4** shows spatial variation of diarrheal prevalence in different parts of Botswana.

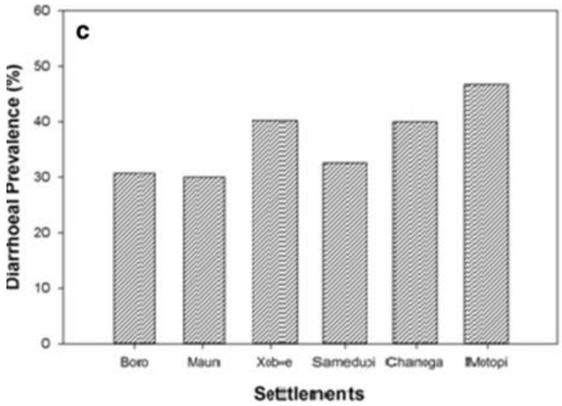

Figure 4 Spatial variation of diarrheal for peak flooding season (Tubatsi et al., 2015).

4. CASE STUDY III: THE IMMINENT WATER STRESS IN AFRICA AND MIDDLE EAST

The simplest definition of water stress is the demand exceeds the available amount or poor water quality restricts its use (Kreft et al., 2013). One of the biggest issues that is inevitable nowadays in Africa and the Middle East is water stress particularly in areas of Gulf nations. The impact is so bad that the authorities declare this situation as an obstacle for human development (UNDP, 2013). It is also reported that around 1.8 billion people from different countries and regions will be facing water scarcity by 2025 (Programme W. W. A. 2012). Therefore, the world needs to be prepared for many water related crisis in near future. It is important to note that all these problems are highly unlikely to be the result of nationwide water shortage or scientific incapability to maintain future water supply, instead population growth, unplanned water allocation, unchecked demand and lack of investment in new infrastructures will be the main contributors. In addition, the projection of climate change indicates that East and North Africa will become hotter and drier which would lead to water stress for additional 80 to 100 million people in the region (Islam & Susskind, 2015).

It is also reported by Islam & Susskind (2015) the unavoidable forthcoming water stresses among the countries in the Nile Basin. There are 10 countries in the Nile Basin: Democratic Republic of the Congo, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, Tanzania, Uganda, and Eritrea. All these countries are mostly dependent on this river's water for their daily needs. However, the prediction says that the population of Nile Basin countries will exceed 700 million in next 25 years which is double than today's population. Also, the creation of new countries changes the picture of water distribution among the nations. It is highly likely that the regions living in downstream of Nile Basin will face serious water stress if they do not make sustainable policy to the nations living close to upstream.

5. CASE STUDY IV: FLINT, MICHIGAN, USA WATER CRISIS

The recent water crisis in Flint, Michigan, United States of America is an example to understand what could happen because of negligence in water management. In April 2014, Detroit Water and Sewerage Department switches the source of water supply to the city of Flint from Lake Huron to Flint River. The reason behind the shift is construction of a new pipeline in Lake Huron (Lin, Rutter, & Park, 2016). The pH level of Flint River water is low and experts expressed their concerns at the time when the decision was made. Despite having critical comments, the shift took place. The level of lead presence in children's blood between 2010 and 2015 in the area of Flint had normal patterns for the third quarter of the year. After the switch of water source, experts tested blood samples of children and observed a high level of lead. It is amazing to see that in a country like USA the local government did not acknowledge the issue until October 2015 despite having all the evidences. The state government took three more months to the declare state of emergency (Morckel, 2017). This problem would have been tackled at the very beginning if corrosion control chemical had been added to the water when the switch was made to Flint River (Torrice, 2016). **Figure 5** shows the decolourisation of water due to the presence of lead. The first sample was collected on 15 January 2015 where the lead colourisation was less compared to the specimen collected on 21 January 2015. The correlation between lead concentration and the corresponding colour is visible in the picture. The changes in blood lead level of children under the age of 6 after Flint incident is shown in **Figure 6**.

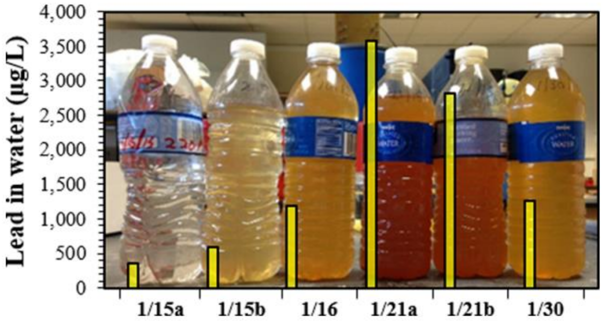

Figure 5 Decolourisation of water because of the presence of lead (Pieper, Tang, & Edwards, 2017).

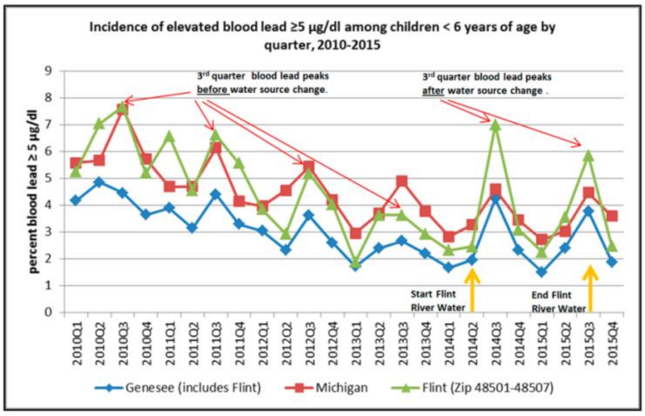

Figure 6 The blood lead level of children under the age of 6 before and after the incident in Flint (Laidlaw et al., 2016).

6. SOCIAL IMPACTS

There is a close relationship between water quality and the socio-economic status of the community. It is essential to know what are the main costs involved in improving water quality, who are the cost bearer and who will be the beneficiaries of the good quality water. Usually farmers, environment and local authorities, private households and building developers are the main contributors of the cost. The status and quality of life of the local community rise which benefits everyone who lives in the area. By taking simple measures such as reducing fertilizers, crop rotation, soil sampling, awareness programs, good managements of septic tank and sewage and reducing house and road run-off, the quality of water can be improved with minimum cost. These initiatives not only take care of water quality but also protect the water ecology.

The depletion of groundwater also has adverse effects on socio-economic status of a community. It is obvious that the dry land requires more digging to draw water from deeper level (provided the existence of deep aquifer system) which ultimately raises the pumping cost. In this case only wealthy people can afford the expenses and inequity issues arise. The control of good quality water may also become the reason of social abuse.

7. FACTORS AFFECTING THE WATER QUALITY

Understanding the problem is the first step to the solution. It is very important to know what causing the quality degradation or underground depletion and then develop the frameworks for solving the issues. Factors influencing water stress and quality include the followings:

- Rapid unchecked population growth.
- Change in quality of life.
- Rising demand for food and energy.
- Unplanned sanitation system.
- Less care in personal hygienic practices.
- Lake of awareness and public education.
- Not maintaining sustainable groundwater extraction.
- Creation of new countries.
- Higher use of fertilizers and pesticides.
- Cruel business policies, greed and geopolitics.
- Poverty.
- Unplanned irrigation.
- Climate change.

8. PROPOSED MEASURES

Public awareness about the importance of safe water for human health probably stands as the first item in the list that needs to be taken into consideration. Improved quality of sanitation system and taking care of personal hygiene can reduce the risk of spreading communicable diseases. There are number of actions such as proper disposal of stool and waste, washing hand adequately, clean and safe drinking water help reduce the number affected people. There is an urgent need to set up more programs like water, sanitation, and hygiene (WASH) to create awareness which will control and prevent spreading of water borne diseases at household level. There are technological initiatives that can be taken to find the solution. The idea of meeting the water demand by adopting water conservation and recycling methods along with efficient use of water sounds interesting to be taken into consideration.

In case study III, we have discussed the undesirable situation in Nile Basin. A closer look in these regions' water consumption suggests that evapotranspiration and irrigation are the primary sectors for water use. Careful selection of efficient agricultural processes such as drip feed irrigation, and plantation of drought tolerant crops and livestock, and developing technologies to collect water from irrigated fields and reuse could help the communities to reduce their risk of water stress.

The challenge of climate change and the associated adaption options to tackle the issues is studied by number of experts (Biagini et al. 2014; Smit & Skinner, 2002). They have identified a range of actions such as capacity building, management and planning, policy, physical infrastructure and financing that can be adapted to build a sustainable environment. They have also described the efficient measures for agricultural processes which are helpful to reduce the water usage without hampering the gross production. Other potential sources of clean water are desalination and wastewater treatment, which are relatively expensive.

9. EXAMPLES OF TERTIARY EDUCATION ON WATER

It is clear from the above discussion that the world is facing some serious problems in providing adequate and safe water to its inhabitants, and the situation is going to be worsening if not handled properly. The future of the earth is on our hands, and it is crucial that we are fully equipped to tackle all the challenges that threaten our existence. Therefore, we have no choice but to educate our young generation about the importance of adequate and safe water and what are the challenges that need to be tackled to continue our access to safe water.

It seems like current tertiary education systems in many countries are not on the right track that their graduates can potentially contribute to the grand water crisis (Rahman, 2017). Here we have discussed the engineering education systems in two countries, Australia and Bangladesh to understand the situation. Table 1 includes water related subjects/units taught in different disciplines in Australia and Bangladesh.

Table 1[†] Water related subjects taught in Bangladesh University of Engineering and Technology (BUET) and Western Sydney University (WSU), Australia.

Degree	**Subjects/units**	
	BUET	**WSU**
Bachelor of Science in Civil Engineering	WRE 201: Fluid Mechanics WRE 301: Open Channel Flow WRE 303: Hydrology WRE 401: Irrigation and Flood Control WRE 407: Groundwater Engineering WRE 411: Hydraulic Structures CE 433: Environmental Engineering IV	300762.2: Fluid Mechanics 300737.4: Environmental Engineering 300765.2: Hydraulics 300983.2: Surface Water Hydrology 300989.1: Hydrogeology 300992.1: Water and Wastewater Treatment 300993.1: Water Resources Engineering 300991.1: Statistical Hydrology
Bachelor of Science in Mechanical Engineering	ME 201: Basic Thermodynamics ME 321: Fluid Mechanics-I ME 323: Fluid Mechanics-II ME 303: Convection, Boiling, Condensation and Mass Transfer ME 421: Fluid Machinery ME 403: Power Plant Engineering ME 423: Fluids Engineering	300762.2: Fluid Mechanics 300760.1: Thermodynamics and Heat Transfer 300759.1: Thermal and Fluid Engineering
Bachelor of Science in Chemical Engineering	ChE 203: Chemical Engineering Thermodynamics I ChE 205: Fluid Mechanics ChE 307: Chemical Engineering Thermodynamics II ChE 409: Corrosion Engineering ChE 485: Industrial Pollution Control ChE 483: Environmental Science II	
Bachelor of Science in Water Resources Engineering	WRE 110: Intro. to Water Resources and Civil Engineering WRE 201: Fluid Mechanics WRE 301: Open Channel Hydraulics WRE 327: GIS and Remote Sensing CE 371: Environmental Engineering WRE 303: Hydrology WRE 423: River Engineering and Basin Management WRE 417: Groundwater Engineering WRE 419: Irrigation and Drainage Engineering	

[†] Information related to different courses is collected from undergraduate booklets published by BUET and WSU.

As can be seen, water related subjects are taught in different disciplines in both countries at tertiary level. While mechanical engineering mostly deals with properties (thermodynamic and mechanical) and energy extraction from water by developing machineries, civil engineering focuses on hydrological cycle, water treatment, water supply, water management, pollution, irrigation and flood controls. In Bangladesh, chemical processes involved in water treatment are taught in civil engineering to some extent; however, extensive learning of this topic can only be achieved in chemical engineering and water resources engineering. In the case of Australia, civil engineering students are taught water treatment process at the basic level. Recently, Bangladesh have introduced a new discipline, water resources engineering, which seems to be a very good initiative in enhancing its capability in water management and control considering the current situation of the country in terms of population, floods, water pollution and water demand. With that being said, let us discuss the education delivery methods in these two countries for water subjects at university levels. In general, BUET contains more water engineering subjects than WSU. **Table 2** represents the basic differences in education delivery methods in these two universities, which affect their graduate attributes.

Table 2 Tertiary education delivery methods in Australian and Bangladeshi Universities.

Item	Australian University	Bangladeshi University
Learning process	*Active learning.* Students are involved in teaching process. They often ask questions if they are confused about the contents of the lecture. They are divided into groups and assigned with tutors that they may have extra consultation time about the topic. Advanced learning management system such as *vUWS* at Western Sydney University is used for teaching where the teaching team uploads necessary learning materials and test results. The system is connected to enrolled students' cell phones; therefore, whenever there is a new material in the system, students receive notification.	*Passive learning.* In most institutions, students attain lectures face-to-face and make note of the topic from blackboard. There is little interaction among the lecturer and students None of the universities in Bangladesh have introduced effective learning management system yet.
Staff	Lecturers, tutors and demonstrators are generally experienced and up to date to the advancement in the field. Most of them are involved in active research.	Lecturers and demonstrators teach subjects for years without upgrading the contents. Most of the academics are not involved in high quality research.
Technology	Teaching delivery method such as blended learning is being implemented. Enrolled students always have access to the learning materials including recorded lectures. The sessional resources (equipment and measuring tools) are precise and handy.	Lectures are not recorded and learning materials are not widely accessible via online system. Equipment may not be adequate to carry out effective lab classes.
Interaction	Discussions are encouraged and private counselling is available.	Teacher-student interaction is not a regular practiced culture. Asking questions is discouraged.

Real life challenges	Students are required to complete a number projects that are related to real life problems. Therefore, graduates from these institutions are comfortable dealing with practical problems assigned by their employers. All the case studies presented above could become projects for different groups studying civil, chemical or mechanical engineering.	Too much priority is given to theoretical understanding in these institutions which make their graduates less confident in practical situation. Current education system is producing handicapped graduates who are not evolved enough in handling real life issues which ultimately restricting them to contribute to global challenges such as water crisis.
Professional experience	Students are required to complete 12 – 48 weeks internship in industries.	Students complete an industrial attachment period of 4 weeks.
Academic writing and oral presentation	Students have to complete several projects and individual thesis, and subsequently present their findings in front of an advisory committee. They have to submit their final reports in an acceptable format.	Students are required to complete a project in their final year of study. Tough officially it meant to be an original work in the form of academic writing; often it is written and presented in a casual way. Students generally do not get chance to develop their writing skills.

As can be seen from **Table 2**, learning methods in Australia is more interactive. Students are well prepared for real life challenges at the completion of their graduations due to greater involvements with real world projects in studies. Most of them are familiar with the new technologies in water field and feel confident in their job interview. Whereas, in Bangladesh, tertiary students are more focused on textbook kind of study and they have to struggle a lot to make their transition from student to professional career. Students with good grades from these universities are often offered scholarships from western universities for postgraduate studies; however, they are required to struggle a lot to keep up with the local students. The curriculum of tertiary education in countries like Bangladesh needs major changes incorporating effective learning management systems and blended learning methods with a right balance between face-to-face and online components. This will allow preparing students to meet water challenges and sustainable development in a better way.

10. CONCLUSION

This paper presents a number of case studies that are related to water resources management, water contamination and treatment, water stress and risk. It has been found that there are numerous challenges in water management. Poor water management is present in many countries, ranging from developing to developed nations. Arsenic contamination in Bangladesh has affected over 60 million people – a situation that needs urgent solution. Even in USA, poor response can lead to serious water contamination as discussed with Flint lead poisoning. The water shortages in the African and Middle Eastern countries will worsen in near future due to climate changes. The tertiary education systems in developing countries like Bangladesh are compared with Australia as a basis to differentiate the capabilities of the water engineering graduates. It has been shown that Bangladeshi engineering courses are rich in subjects, but delivery methods need enhancement by including blended learning methods and more real world case studies to produce graduates who can solve water crisis in Bangladesh.

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Hydrology Education in Australia: Challenges & Opportunities

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Abstract

Students usually find water engineering concepts difficult to grasp. This problem gets compounded once they move to senior level water related subjects. Undergraduate Civil Engineering students usually undertake subjects covering basic fluid mechanics and engineering hydraulics in junior years. This is followed by a subject in engineering hydrology in the senior year. It is during the senior year where a large proportion of students tend to struggle with the concepts presented in engineering hydrology. But the rapid urbanization trend caused by an ever-increasing population growth around the globe has necessitated all Civil engineering graduates to have a working knowledge of engineering hydrology. This is because of the increase in frequency and magnitude of floods and the potential for higher damages as a result of urbanization. This also means the increasing need for hydrology concepts to be covered in an undergraduate Civil engineering degree curriculum.

The rapid advancement in information technology has been a blessing to engineering educators willing to take the plunge and make use of these technologies to address the challenges to improve student understanding of hydrology concepts. This paper discusses some of the techniques that can be used to improve student engagement and learning outcomes in engineering hydrology education. Examples on the author's experience on how these techniques have been developed using sound pedagogy and implemented using the IT tools are presented.

Keywords: Engineering education, hydrology, information technology, flood

1. INTRODUCTION

Australia has 40 full universities and around 130 other tertiary education providers (Norton & Cakitaki 2016). These higher education providers have responsibilities to ensure that they meet the quality of education prescribed by Tertiary Education Quality and Standards Agency (TEQSA)[†], the agency responsible for ensuring educational standards set by the government. In addition, various professional bodies prescribe their own requirements for accrediting respective professional programs. It is noted that, in Australia, overall higher education matters are the responsibility of the Department of Education and Training[‡].

Engineering institutions take on a unique place in the tertiary education sector. One of the reasons is the expectation by the general society that engineering graduates come out of a university ready to solve real-world engineering problems. While this may not be reasonable nor practical, this is also the expectation of employers who want to extract maximum benefits from their fresh employees. To

[†] https://www.teqsa.gov.au
[‡] https://www.education.gov.au

manage such expectations and to meet the requirements of the accrediting body, Engineers Australia[§] (EA) in the Australian context, most engineering institutions aim to produce '*market-ready*' graduates by giving them theoretical knowledge complemented by laboratory work and field experience. One way to infuse the field work requirement is through incorporation of work integrated learning (WIL), usually using work placements, within an engineering curriculum. This is also a requirement of EA – typically 450 hours of industry experience is required before a student can graduate with an accredited engineering degree. Currently, 38 universities and their subsidiaries have their engineering programs accredited by EA at different levels[**].

In the current context of ongoing discussions on climate change and its impacts, compounded by the employers' expectations to have graduates who are ready to address these challenges, the need for hydrology education to be incorporated within undergraduate engineering curriculum is gaining increasing importance [e.g., Lee (1992), Seibert, Uhlenbrook and Wagener (2013), Habib and Deshotel (2018)]. The challenge is to balance the need for hydrology education within an undergraduate engineering degree with students' capacity and maturity at this level. As such students find fluids related subjects challenging (Cheng et al. 2002) and educators face major hurdles in conveying basic fluids principles. This gets even more complicated when the data from student feedbacks are used as an avenue to gauge an academic's competency; especially when these results are used to determine their career progression (Young 1993).

In the midst of the abovementioned challenges, the rapid advancement in information technology has been a blessing to educators who are willing to take the plunge and make use of these technologies [e.g., Shrestha, Wang and Russell (2016)]. Use of these technologies, to a limited extent, will address the challenges of improving student understanding of hydrology concepts. This paper discusses some of the challenges we face and techniques that can be used to improve student engagement and learning outcomes in engineering hydrology. Examples on how these techniques have been developed using learning & teaching pedagogy and implemented using the IT tools are highlighted in this paper.

2. TECHNOLOGICAL DEVELOPMENTS

Eloquently quoted by Jain and Singh (2003), "*May beautiful waters be pleasant to us to drink and acquire happiness, and flow with health and strength to us*," the verse from one of the oldest Hindu scriptures (YajurVeda, 36.12) clearly highlights the importance of water. This also means the engineering educators have inherent responsibility to train students to effectively harness, manage and make optimal use of limited water resources that is available for use. In addition, drought and flood management, as a result of the climate change (whether this be natural or anthropogenic), are other important aspects that cannot be forgotten in the mix. This brings us to hydrology education and its significance.

Lee (1992) has passionately argued the need to include hydrology in undergraduate engineering programs. This was not long after the challenges of teaching hydrology were identified by Nash et al. (1990). We have come a long way in hydrology education since the series of questions posed by the ASCE Task Committee on Water Resources Education and Training (TCWRE) in 1985 (Committee 1990) followed by the establishment of IAHS/UNESCO Panel in 1989 (Nash et al. 1990). More recently, the need for a cultural change in teaching hydrology to impart new skill sets was discussed by Seibert, Uhlenbrook and Wagener (2013). Ruddell and Wagener (2015) argue that despite an increasing attention to hydrology education in recent decades, we are still faced with multitude of challenges in the new century. They argue that there is a need to develop formal pedagogies that make use of the development in technologies to meet the unique needs of the present world. So, how can we take advantage of the technological advancements?

[§] https://www.engineersaustralia.org.au/
[**] https://www.engineersaustralia.org.au/sites/default/files/2018-10/Web_List_V30_181015.pdf

Shrestha (2016b) describes reasons for increasing popularity of different L&T pedagogies as a direct result of advancement in Information Technology (IT). The acceptance by students and benefits they gain through use of technology in hydrology education have also been illustrated by Shrestha, Wang and Russell (2016). They found that the use of appropriate technology in hydrology education resulted in significant improvements in student engagement and student success. Student responses to the survey questionnaires distributed at the end of the semester were also positive, stating that they (the students) enjoyed the new learning environment and the technology used in classrooms assisted in their learning. The researchers concluded that the use of technology was important in an authentic and effective socio-material learning process (Shrestha, Wang & Russell 2016).

One of the major suggestion made by Shrestha, Wang and Russell (2016) was the critical role played by the '*fit-for-purpose*' learning spaces. They recommended the need to modify traditional lecture theatres and tutorial rooms to alternate learning spaces that can take advantage of the L&T design using advancement in IT. This was the rationale used in the design and development of Collaborative Learning Spaces (CLS) at Western Sydney University, as described in Shrestha (2016a). He concluded that properly designed learning spaces contribute to effective student learning through student engagement (facilitating teamwork). The benefit gets amplified when authentic real world engineering problems are incorporated in the learning design (Habib & Deshotel 2018) and teams are used to find solutions to such problems (Zuwała & Sztekler 2018).

3. EDUCATIONAL PEDAGOGY – FUSION OF DIFFERENT APPROACHES, EXAMPLE IMPLEMENTATION AND OUTCOMES

The Task Committee on Water Resources Education and Training (TCWRE) of the ASCE Water Resources Planning and Management Division (WRPMD) in 1985 (Committee 1990) conducted a survey and found that water-related courses were the most important courses identified by both the educators and practitioners. This is mainly because the graduates are not adequately prepared to solve water related problems. They identified the need for a better balance between the basic principles and critical thinking as well as analytical skills in hydrology education. They recommended that greater emphasis be given to the use of computers (IT) in hydrology education. This was during the period when IT was at its infancy,

In the last three decades, there has been significant shift in hydrology education. Advent of the Internet, its wide-spread availability and easy access in the 2000s have given rise to the Google generation, where answers are available at the flick of a mouse button. The challenges to educators and the opportunities generated by this advancement in IT have been described by Ruddell and Wagener (2015) in their paper, titled, "*Grand Challenges to Hydrology Education in the 21st Century*." They discuss the need to incorporate interactive data, modeling and visualization in the development and adoption of evolving student-centred pedagogies. The move from the traditional '*chalk and talk*' learning & teaching (L&T) method, where students are passive recipients (usually taking on the role of a '*sponge*') has been replaced by interactive sessions where learners are active and engaged participants. This has given rise to many strategies, ranging from the traditional face-to-face teaching supplemented by limited IT usage in classrooms to fully online techniques (e.g., online courses offered by Open University[††] and Udacity[‡‡]).

A combination of the traditional face-to-face teaching complemented by use of advancement in IT is a balanced mix of both the traditional and online techniques. In this blended approach, the educator takes on the role of a facilitator (Pathirana et al. 2012). The use of blended learning strategies in implementation of Project Based Learning (PBL) using Flipped Classroom (FP) pedagogy and use of CLS (to facilitate this L&T strategy) have been discussed by Shrestha (2016a) and Shrestha (2016b).

[††] https://www.open.edu.au/
[‡‡] https://www.udacity.com/

Significant benefits to student learning outcomes of this L&T pedagogy have also been highlighted by Shrestha, Wang and Russell (2016).

The hybrid approach adopted by Shrestha (2016b) was well received by his students enrolled in hydrology. In the end of semester student feedback questionnaire, the students responded by stating that not only did they enjoy the teaching method adopted and the use of technology, but they were also better prepared to face the real-world challenges; mainly as a result of the PBL strategy adopted in the subject. In addition, the cohort of students found improvements in teamwork and presentation (both oral and written) skills.

4. CONCLUSIONS

The need to include hydrology education in undergraduate Civil and Environmental engineering courses have been recognized over three decades ago. However, the challenges to hydrology educators are many and varied. The demand from employers and the requirements of the accreditation agency have driven educators to develop L&T material that balance the theoretical knowledge with practical exposure. Lately, the issue of hydrology education has been further complicated by the need to incorporate the effect of climate change. These requirements can be addressed by developing material that can take advantage of the rapid advancement in information technology. But, use of these technologies require educators to dive into new innovate L&T models where the learners take responsibility for their own learning and educators take on the role of a facilitator.

The hybrid approach developed and adopted seems to be an ideal opportunity which can take advantage of the evolving technology. The anecdotal evidence suggests that this approach encourages learners to better engage and achieve better learning outcomes.

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New and Emerging Developments in Power Engineering

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Abstract

Electrical Engineering is a well-established field of study and power engineering is the oldest sub-discipline of it. Electrical Engineering field has expanded much rapidly over the last few decades. The traditional developments were large power stations, very long high voltage (HV) transmission lines and even across national boundaries. With increasing concerns about global warming and greenhouse gases, the electricity energy generation, conversion and utilization has accelerated developments in smart and micro-grids, distributed generation and localized renewable energy generation. Due to new developments, power engineering programs are being modernized to include new areas such as smart grids and distributed generation, renewable and sustainable generation, smart and micro grids with smart and two-way communication. It is expected that the future of power engineering will concentrate on alternative electrical energy sources, smart power conversion, DC power systems, smart drive systems, distributed generation, electric vehicles and distributed storage, superconductors and other highly efficient and smart materials. Electric vehicles (EV) and associated battery storage will require new approaches to operate the modern power systems. EVs would be acting both as consumer and provider of energy to power grid. Future graduates will have extensive knowledge in new and emerging power systems, communication and smart and two way power flows. This paper will outline these new and emerging fields and future directions in Power Engineering.

Keywords: Power Engineering Education, Engineering Education, Electrical Engineering Education

1. INTRODUCTION

Electrical Engineering is a well-established field of study and power engineering is the oldest sub-discipline of it. Electrical Engineering field has expanded much rapidly over the last few decades with rapid advances in solid-state electronics, communication, computer systems and microprocessors, computer control, artificial intelligence, smart grids and smart metering etc. [1-4]. It was rather natural to accommodate new developments in already crowded curricula by removing or rationalising existing course structures. Due to new developments, new degree programs have emerged as specialist disciplines e.g. electronic engineering, computer engineering, communication engineering, control engineering and of course electrical power engineering and even highly specialised sub-discipline of photovoltaic and solar energy[5]. Power engineering education has gone through various stages including earlier golden era of large-scale electrification, later an era of automation and computer control and more recently an era of restructuring/ deregulation, distributed generation and smart grids [6-16]. It is expected that the future of power engineering will concentrate on alternative electrical energy sources, power quality issues, smart drive systems, distributed generation and electric vehicles and better forms of storage, use of superconductivity and other highly efficient and smart materials [17-24].

Large numbers of Australian and overseas universities eliminated power engineering teaching and research from their curriculum due to lack of student interest. It has produced a crisis in power and energy engineering education. With restructuring and rationalisation in electric utilities, many qualified power engineers have left the industry and very few have taken their positions. There is ensuing crisis in industry and academia in the next few years when such an important area of economic activity will not be well maintained, though some universities have revitalised their power engineering programs [4-8]. It is essential that power engineering should be taught as an essential component of any electrical engineering program with more emphasis on power conservation, new forms of electricity generation including renewable sources, embedded/distributed generation, power quality and EMC issues [22-24].

2. STATE AND FUTURE CHALLENGES IN TEACHING

The classical skills such as mathematics, physics, circuits, electronics, signals & systems, communications and control are still the building block of power engineering education. These skills are still relevant even though traditional power systems with centralised generation, H.V. transmission and distribution are being replaced with new structure such as-smart /micro grids- with significant generation at consumer's end with power electronic converters. It has created many opportunities for engineers especially in the area of smart grids, distributed generation, energy conservation and sustainability, environmental issues.

The traditional components of electrical power engineering are as follows:

- Electrical machines
- Electrical drive system
- Power electronics
- Power system analysis
- Power generation, transmission and distribution
- High voltage engineering
- Power system protection and control

Some newly emerging areas of technologies also require the essential elements of electrical power engineering e.g. Mechatronics and robotics require essential of power electronic and control, electrical machines and drives.

2.1 ELECTRICAL MACHINES

This subject needs to be taught more from a practical application point of view. There needs to be more of an emphasis on new developments.

- Power supply design
- Applications in power systems (STATCOM, Power factor corrections)
- Application in traction and electric and hybrid vehicles
- Soft switching techniques
- Power quality and EMC
- Power Electronics applications in renewable energy conversion and energy storage

2.2 ELECTRICAL DRIVE SYSTEMS

It covers electric motors, power converters and associated control as an integrated system. This area needs to be taught as an integrated area with possible use of multimedia and computer simulations. New developments in microprocessors, control techniques and DSP applications and dynamics can be easily incorporated.

2.3 POWER SYSTEMS ENGINEERING

In addition to traditional area, some new additions need to be included by moving some of traditional topics such as load flow, planning etc. to postgraduate (PG) level.

- Distributed/ embedded generation
- Effects of penetration of new and renewable energy sources
- Power quality issues
- Developmental electricity markets, short term load forecasting
- Business aspects of electricity markets with multiple players
- Smart and micro-grids and smart metering
- Smart load management
- Consumers acting both as consumer and producer

2.4 POWER QUALITY

It has taken on significance due to application of power electronics in industry, computer application and transportation. There are stringent standards/requirements covering such issues as EMC certifications. This area can be of interest to all electrical/ electronic/ computer/ telecommunication engineers or even mechatronic engineers. It can easily cover important areas of EMI/ EMC, Power Quality and mitigation techniques.

2.5 RENEWABLE ENERGY SYSTEMS

This subject can cover fundamentals of generation and distribution systems involving new methods of generation such as:

- Wind and solar energy and conversion to electricity.
- Fuel cell and other alternative sources of electricity generation, OTE, wave energy.
- Economics of green power.
- Operational aspects of large penetrations of renewable energy in power systems including smart grids.
- Energy storage at grid and consumer level.

3. PRESENT STATE AND FUTURE CHALLENGES IN RESEARCH

Existing power systems are based on few centralised thermal and hydro power stations and employing large synchronous generators. The existing power systems analysis use traditional models of synchronous machines to analyse and compute short circuits, load flow studies and expansion planning etc. In recent years, a large number of wind, solar and other smaller generating units are being connected with power electronic converters. Further, many industrial drives with traditional motors and new types of motors are being used which are electronically controlled and operated. New techniques of analysis, design and operation are to be developed and incorporated in the curricula. Figure 1 shows a traditional and future power system.
A microgrid is a discrete energy system consisting of distributed energy sources (including demand management, storage, and generation) and loads capable of operating in parallel with, or independently from, the main power grid. The primary purpose is to ensure local, reliable, and affordable energy security for urban and rural communities, while also providing solutions for commercial, industrial, and federal government consumers. Benefits that extend to utilities and the community at large include lowering greenhouse gas (GHG) emissions and lowering stress on the transmission and distribution system.

Micro grids perform dynamic control over energy sources, enabling autonomous and automatic selfhealing operations. During normal or peak usage, or at times of the primary power grid failure, a micro grid can operate independently of the larger grid and isolate its generation nodes and power loads from disturbance without affecting the larger grid's integrity. Micro grids interoperate with existing power systems, information systems, and network infrastructure, and are capable of feeding power back to the larger grid during times of grid failure or power outages.

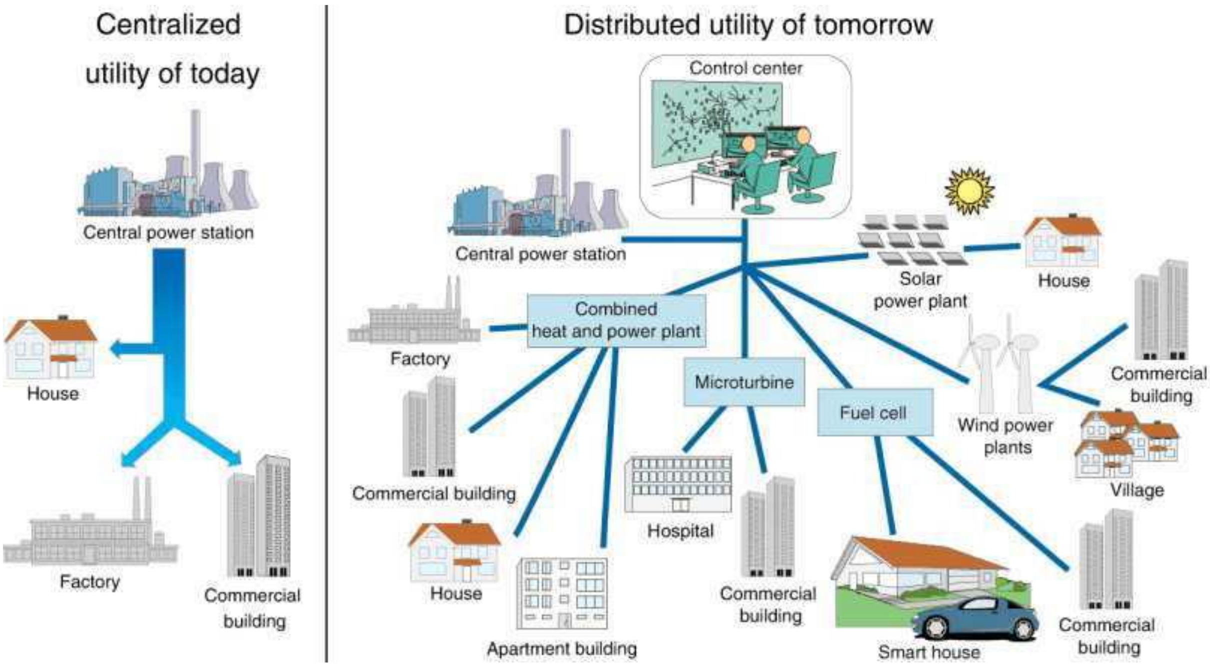

Figure 1: (a) Traditional Power Systems (b) Distributed Power Systems of future

A general look at research activities in universities and research centres and organizations provide an indication of activities as follows: [10-15].

- Renewable Energy
- Electrical Machines Design
- Power Electronics and control
- Power System Protection and Control
- Power Quality and EMC
- Smart grids
- Energy Storage
- EV charging & discharging

3.1 ELECTRICAL MACHINES

- Electrical Machines (Design & Analysis)
- PM or VR machines (generators/motors)
- Permanent magnet couplers, Gears and magnetic bearings.
- New topologies for Electrical Motors/Generators
- Electrical Drives for EV, PHEV, Hybrid EV

3.2 CONTROL

- Vector Control of Drive Systems (IM, PM and VR).

- Direct Torque Control
- Sensorless Control (IM, PM and VR).
- Neuro-Fuzzy Control (IM, PM and VR).

3.3 ELECTRICAL DRIVE SYSTEMS

- Converter Topologies for drive systems
- Soft-switching techniques
- EMC and noise issues
- Electric vehicle Applications

3.4 ENERGY SYSTEMS

- Power Quality / EMC.
- Power Systems Control and Protection
- Renewable Energy Engineering (wind, solar)
- Distribution/Embedded Generation
- High Voltage Engineering
- Load Forecasting
- Power Electronics in Power Systems
- Active filters
- FACTS, PF correction and VAR compensation
- Applications of superconductivity

3.5 POWER ELECTRONICS

- Soft-switching techniques
- Electronic ballasts
- Converter topologies
- Power electronic control for renewable energy systems
- Grid interfacing technology for batteries/utility scale energy storage
- EV, PHEV charging stations, fast charging

Fuel cell and battery storage/systems development has traditionally been undertaken by chemical engineers and other physical scientists and rarely by electrical power engineers. There is certainly need to develop some research initiatives on the effects of such technologies on power systems.

- Penetration of Electricity from fuel cells/ solar and wind energy systems.
- Large Scale use of battery charging for future electrical vehicles.
- Smart/Micro Grids and distributed generation
- Smart load management techniques

Another area, which is still in its infancy, is the electricity as trading commodity on the financial markets. As electricity cannot be stored so easily as traditional commodities as products, such as metals, beverages, foods etc. There is urgent need for universities to develop short courses for business executives, future brokers and traders, investment bankers to provide some essential elements of electrical generation, transportation, distribution and utilization for business communities, through existing business studies programs or stand-alone short courses. The power academic community can take this important opportunity to develop expertise in short term load forecasting with variable generation, future trading in electricity, demand/supply analysis.

4. CONCLUSION

The paper outlined the state of teaching and research in electrical power engineering. A more innovative approach is required to form research consortia's and develop new and important areas. The future developments in penetration of renewable energy and distributed generation and smart grids will be a challenge to existing and traditional electrical power systems. Further the increased penetration of renewable sources and Electric Vehicles with both as consumers and storage of electricity. The energy storage will be major issues for future power education.

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ENERGY STORAGE: WHERE SHOULD IT GO and HOW SHOULD IT BE PRICED?

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Abstract

This paper analyses the impacts of battery energy storage located in typical low and medium voltage radial distribution networks. Various options for battery capacity and location have been considered and the resulting feeder loads and voltage drops modelled on a radial load flow program. Both a generic 10-node low voltage feeder off a 10-node medium voltage feeder and an actual 77-node low voltage feeder were modelled. Consistent results were obtained with both models. The paper concludes that a solution that is near optimum and offers economy of scale is to share storage among a group of about 25 to 30 residential units. Energy storage pricing issues are also discussed, and the conclusion reached that a flat net energy tariff regime, coupled with a power/energy type price structure would be the simplest and easiest to implement.

Keywords: Radial electricity feeders, embedded solar-PV, battery energy storage, optimum sizing of storage, optimum location of storage, radial feeder load and voltage drop.

1. INTRODUCTION

The solar photovoltaic (PV) market has undoubtedly shown a turning point in recent years. While the global PV cumulative installed capacity was just 1.4 GW in the year 2000, and had grown to 5.4 GW in year 2005, its installation experienced a tipping point with annual 30-75% increases since that date. During 2012 and 2013, 30 GW of PV systems were installed each year globally. With this, the global PV cumulative installed capacity reached above 100 GW at the end of 2012 [1], 138.9 GW by the end of 2013 [2] and 300 GW by the end of 2016 [3]. While higher uptake of renewable energy systems in any kind is a blessing from an environmental viewpoint, there can be technical concerns about large-scale integration of such systems with existing networks [4]. Whilst accepting the environmental benefits of solar-PV, the [partial] supply independence it offers to customers and making possible the evolution of "prosumers" [5] who can trade with the market, there are concerns within the industry that the extent of these benefits will depend on system configuration and distributed generation (DG) system penetration levels [6, 7]. As an example, a typical PV system output starts declining sharply in late afternoons, whilst this is the time that household load peaks. In addition, this concurrent drop in PV load and rise in the load amplifies the rate of change of demand from the grid and incurs stability risks (see e.g. [8]).

In this paper, the growing number of smaller distributed or "embedded" generators (DG), located mainly in the MV or LV distribution network are analysed, but it is worth noting that embedded generators of larger rating are located in the sub-transmission network. The diagram in figure 1 below illustrates the various storage owners. The five basic generic storage locations are shown as S1-S5, from the HV generator bus (S1), through the transmission system busses (S2, S3) down to local MV and LV (415/240 V) distribution (S4, S5). Examining figure 1, storages such as S1, are located either on or "electrically close" to the generator busses and likewise, storages such as S2 and S3 are located “electrically close” to the transmission busses.

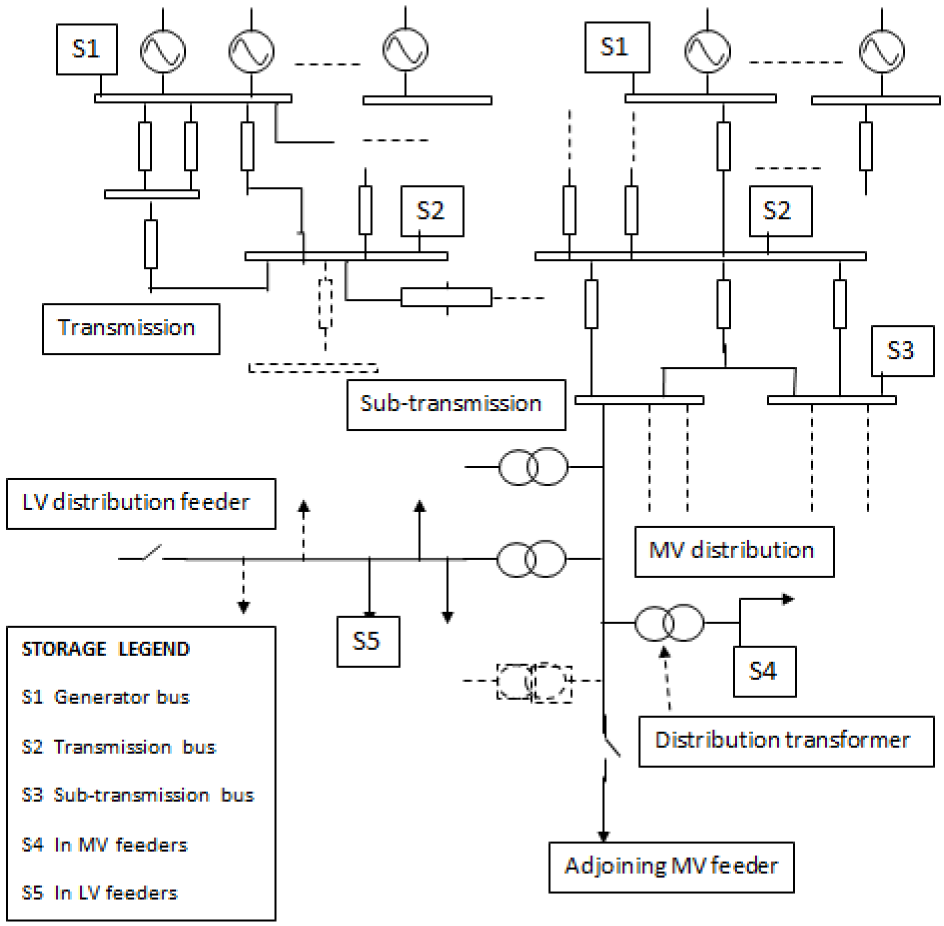


Figure 1: Typical Power System Arrangement and Possible Storage Locations (transformers in the transmission and sub-transmission omitted for clarity)

In this paper, we focus on the optimum operation and management of the storage deep in the distribution network for maximum grid owner and customer benefit using forecast weather and solar data to predict day-ahead plus hourly refinements of battery SOC forecasts. A general discussion of the impact of various ranges of PV-storage uptakes on the grid at the distribution feeder level is included. Instead of losses as in [9] the guiding network design/control used in this paper is to keep voltage within limits and minimise feeder current (which does imply losses as well). Our focus will be on PV-storage because this is what has been occurring in recent years, though the study could be easily implemented to other DGS systems.

2. STORAGE SYSTEMS ALONG PRIMARY AND SECONDARY DISTRIBUTION FEEDERS

2.1 FEEDER TOPOLOGY

Most high/medium and low voltage distribution systems are run essentially as radial networks, with some cross-feeder switching possible ("ring main") via field-operated switches. Increasingly, some of the cross-feeder switches in the MV primary distribution network are being automated. The so-called “2/3” rule, a modified version of the transmission system “n-1” planning rule, is applied to MV ring-main distribution networks. All feeders are designed so that any two feeders should be able to handle the total load carried by any group of three feeders. This assumes that the load on a failed feeder can be split into two halves and each half loaded onto an adjacent feeder to the failed one.

The layout schematic (one-line) diagram for a typical ring-main MV and LV power distribution network is shown in fig 2. We assume each line represents a balanced 3-phase distribution cable, which is true for most cases in Australia with the exception of remote rural lines, which can be either two wire single phase or single wire earth return high voltage (SWER). In both latter cases, there is little or no LV distribution. (The diagram legend is "L" = load; "G" = local generation e.g. solar; "B" = local energy storage, where present). Because the network is operated radial, feeder current is highest at the supply end and voltage drop worst at the feeder extremity, under peak loading conditions (when there is no DG in-feed).

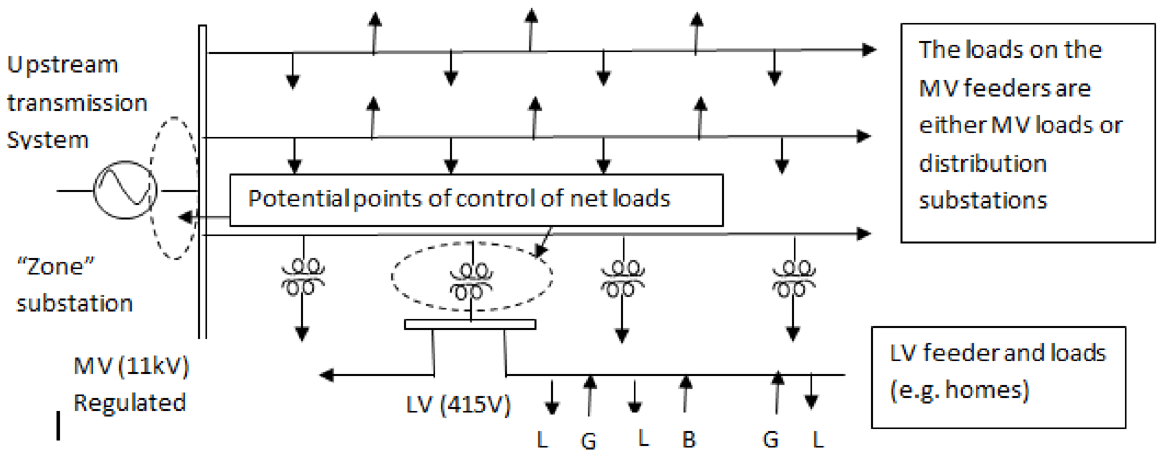


Figure 2: Typical Medium and Low Voltage Ring Main Feeder System layout.

To estimate the grid benefit of storage, consider firstly the radial supply "base case" of fig 3, under peak load and no solar or storage.

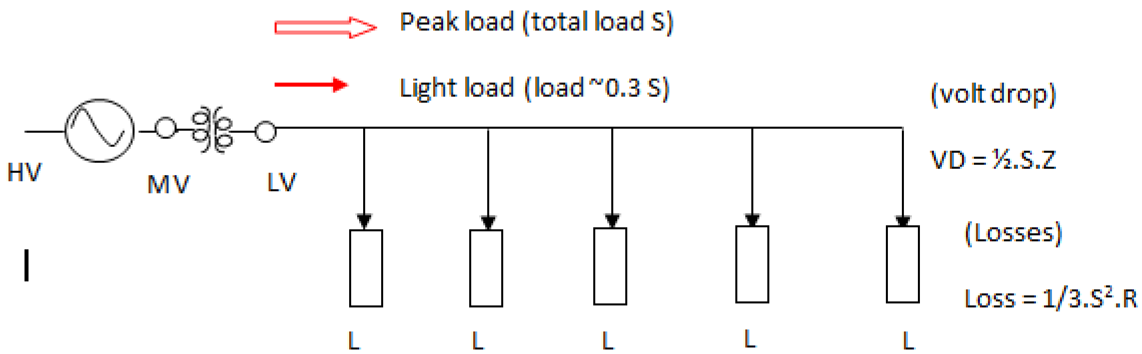


Figure 3: Approx. Uniformly Loaded Feeder – No Storage or Generation (Base Case)

In this idealised "traditional" (base case) supply arrangement, the feeder length and cable size is designed to cater for peak load (current) and maximum allowable voltage drop down the feeder. The losses and voltage drop are based on a theoretically uniformly loaded feeder of uniform (i.e. un-tapered conductors) of total feeder impedance Z and resistance R. Typically, R ~ X, so Z = 1.414 R = 1.414 X. On MV systems, high feeder extremity volt drop at peak load is balanced by applying "line drop compensation" (LDC), a raising of the supply voltage at the zone substation MV busbar under high loading conditions. If the load is concentrated close to the feeder start, total losses and voltage drops will be clearly less for the same feeder total current as the uniform case. Conversely, if the load is concentrated close to the feeder end, total losses and voltage drops will be clearly more for the same feeder total current, up to twice the voltage drop and three times the losses than for the uniform loaded case. Real feeders will of course, lie between these two extremes.

In conclusion, it can be seen that storage (like power factor correction) should be placed deep in the distribution network, with supplementary storage in the upstream transmission network to cater for generator, feeder and transformer failures.

2.2 LOAD VARIABILITY AND DIVERSITY

Major variations in daily energy usage as well as daily and seasonal peak demand occur with single customers, particularly residential dwelling units. In planning studies, aggregated or average daily load curves are used when designing systems, not individual loads (the exception being major high voltage loads, which tend to be more constant, predictable and controllable). The effect on peak demand is often quantified by a "diversity" or coincidence factor. This is quite pronounced after just a few dwelling units – typical diversity factors from a report by Horizon Power for typical Australian LV feeders [10] vary from 1.0 for a single dwelling unit, to 0.46 for 30 dwelling units (e.g. at typical LV feeder level) and 0.4 for 50 and above. Of course, demand management (DM) can have some impact on this variability, especially on peak loading. Diversity factors will vary from country to country and state to state, being a function of connected appliances, local climate and personal daily activity patterns.

Studies on 21 houses at Newington, a Sydney suburb [11] showed that average demand varied from 4:1 from heaviest to lightest user across different dwelling units despite similarities in construction in the houses. Peak demand showed a variation of 10:1 from heaviest to lightest user. In June in a cold-weather episode, average peak demand was 2.0 kVA; highest 3.5 kVA and least 0.9 kVA. Low energy users had a uniform load profile from day to day whereas heavier users peaked at about 3 kVA on 4 days a week, but only 2 kVA on Fridays and weekends. Medium users showed even greater variability.

3. FEEDER MODELLING WITH REAL DATA ON GENERIC AND ACTUAL FEEDERS

To confirm the previous discussion, a generic 10-node MV + LV radial and then an actual LV feeders were analysed under different scenarios by a radial load flow program. Real household load and PV data were obtained from AusGrid [12]. This dataset contains half-hourly load and PV generation data for 300 homes in Sydney from July 2011 to June 2013. Scenarios modelled included:-

- Base case, with no solar or storage, uniform loading;
- Load and solar-PV only, to various levels, without any storage;
- With 1 p.u. solar and 3 p.u.-hrs uniformly spread storage based on average loads (to give a 30% peak lop on average load) uniformly loaded;
- With all storage at the end of the feeder equal to 100% of total feeder load;
- With all storage at the end of the feeder, equal to 30% of total feeder load.

Non-linear as well as uniform load distributions were also modelled, but no significant differences in conclusions were obtained from the non-uniform cases and results have not been listed in the interest of brevity. Firstly, a generic "10 + 10 nodes" model feeder structure was used, consisting of a 10-node MV (11 kV) radial feeder of 4 MVA peak load 6 km long based on taxonomic data for typical Australian distribution feeders in [13], with a 10-node radial LV (415 V) feeder of 250 kVA load and 250 m long, supplied from a distribution transfer at the MV feeder node #8, as shown in figure 4. Loads were assumed to be 3-phase.

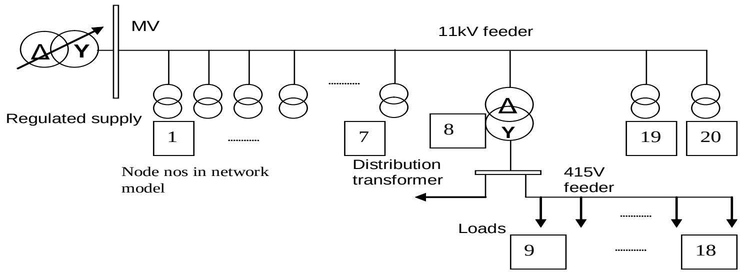


Figure 4: Generic "10-node + 10-node" Radial Feeder Model

A detailed voltage profile down the MV and LV sections of the generic feeder are shown in figure 5. In that study, the feeder had no storage and peak solar-PV input (at midday) equal to the peak evening load. Reactive power control on the solar-PV sources (the inverters) was considered at unity power factor (PF) and then re-run at 0.85 PF lagging at each solar-PV plant and then at linearly varying levels of reactive power, increasing down the feeder:

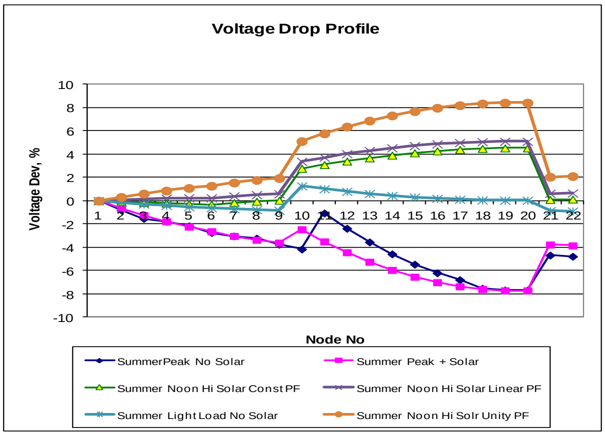
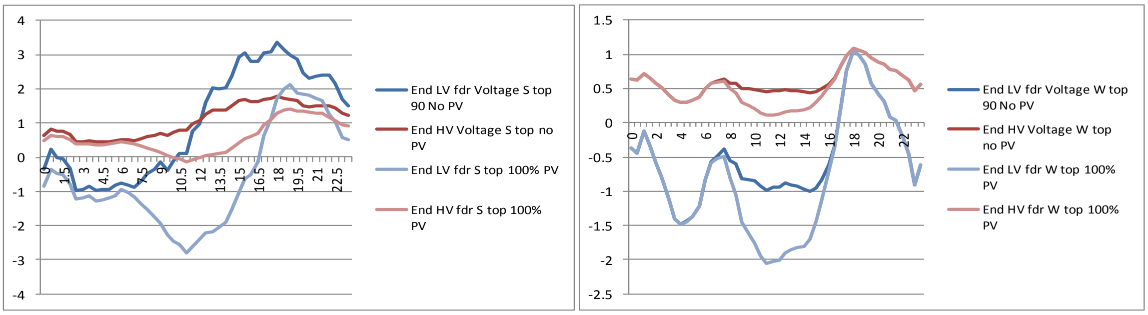


Figure 5: Generic 10-node Radial Feeder Voltage Profile

Summary results for this feeder showing load on the first sections of the MV and LV feeder and voltage drop at the ends of the MV and LV feeder is in Table 4. This time, however, storage was now also considered (lower two cases). The results are for evening peak load conditions except for case 2, which was for mid-day conditions with maximum solar-PV.

A detailed study of 50 homes in the Sydney area containing a mix of load only, embedded solar-PV was undertaken as a part of the CSIRO "Future Grid" project [12]. Detailed half-hourly load and solar-PV data was available. This was analysed again on the generic 10 + 10 node radial MV/LV feeder model and hourly plots of feeder extremity voltage drops obtained. The results are shown in figure 6 a) and b), for the top 10% of summer and winter loads respectively again for varying levels of embedded solar-PV.



a) b)

Figure 6: Hourly Feeder Extremity Voltage Drop for CSIRO "Future Grid" "50 Homes" Data

4. POSSIBLE PRICING REGIMES FOR ENERGY STORAGE

If an energy storage owner is also a load customer (as frequently will be the case), the daily tariff charges on the daily net (load +/- storage) curve will influence storage charge/discharge management. Consider the case where there is sufficient storage to create a flat net (load +/- battery charge/discharge), reducing system peak and eliminating the sharp late afternoon rate of change of net load, as shown in fig 7. If a "time of use" (ToU) tariff is applied, energy costs will be higher in peak and shoulder periods, in which case a flat net (load +/- storage) will incur uneven charges on the customer throughout each 24 hour period.

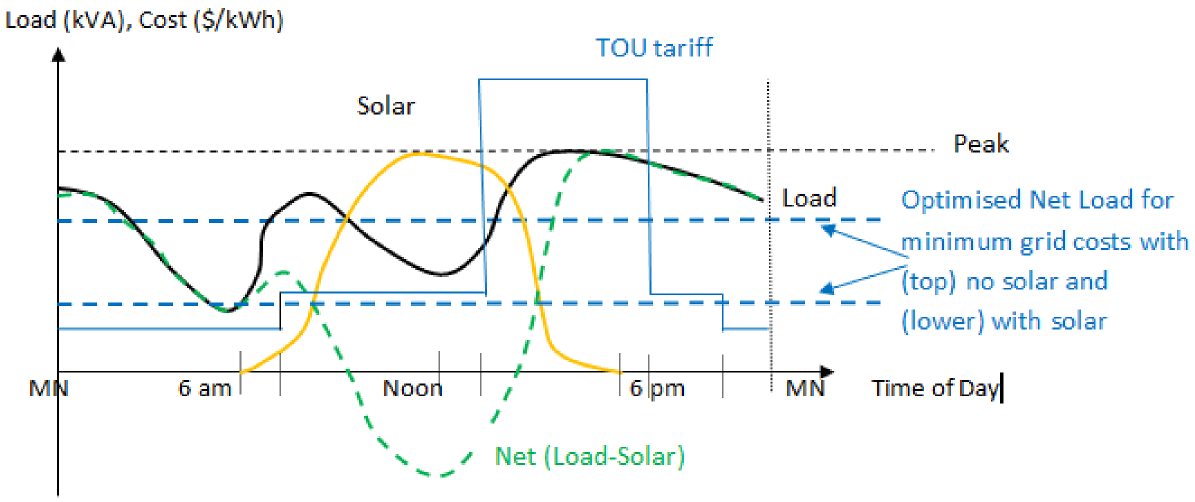


Figure 7: Daily Load Curve with Significant Storage. A flat net load curve will incur uneven tariff charges

Paradoxically, this implies that a flat tariff may be more useful in situations of high local energy storage in the distribution network. With the advent of electric vehicles (effectively mobile energy storage and loads), this situation could be even worse. The case for the flat ToU tariff would be to reward the storage owner for optimising the peak load reduction on the grid regardless of time of day or night.

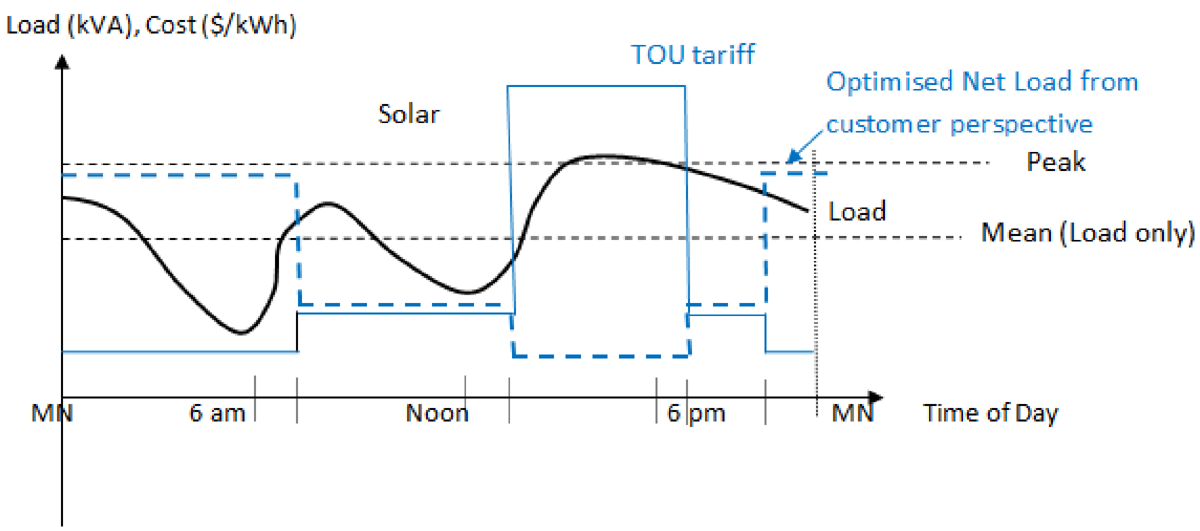


Figure 8: Daily Net Load+/- Storage Curve Optimised from Customers' Point of View

From the customer's point of view, the best strategy would be to place as much load (and energy storage charging) in the off-peak period, with zero or an absolute minimum in peak/shoulder periods as in fig 8. Given sufficient storage on the system (e.g. with proliferation of both static storage and electric vehicles), this could create a new grid peak in the traditional off-peak period, with zero net peak load reduction benefits to the grid. A cheaper tariff may cause a grid load spike when all storages are turned onto their charge cycles at the same time.

Considering now the grid planning perspective, the traditional approach is to limit the grid net peak load to the first contingency or "planning" (usually "n-1") rating of the network, i.e. the blue curve in fig 9.

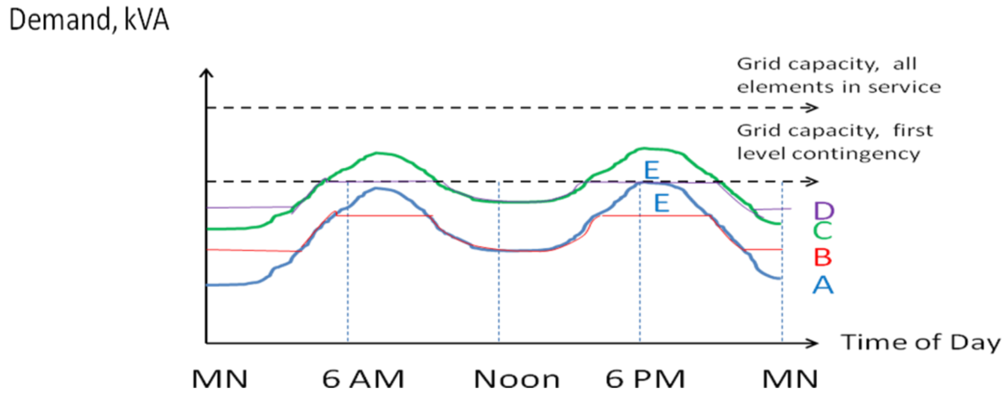


Figure 9: Potential Energy Increase and "Planning" Capacities

A = Load curve without storage, peak = 1st level contingency rating
B = Load curve with storage, potential increase of load = E
C = Potential load curve with storage, increase of clipped peak = E
D = Potential load curve clipped to match 1st level capacity

If, with storage, the load peaks can be lopped then the raw load could be increased to that shown by the green curve, as peak load could be lopped to match first level contingency capacity when required. The reduction in peak load equates to a deferment in future network capital spending to provide peak load capacity (although it does not assist the existing network or sunk capital already spent). The economics then boils down to cost of storage versus cost of grid expansion.
However, closer consideration would reveal that from the grid point of view, it is not necessary to flatten the load curve when the network is in its normal state of all elements in service - the majority of the time. Peak reduction is only required during those contingencies that reduce grid capacity, and only for the period that the contingency exists. "Contingency only" peak load reduction via energy storages would result in the storage owner missing reduced tariff benefits during normal times, and of course network losses, loading and voltage drop would be higher.

5. ISSUES TO RESOLVE?

There are multiple potential uses of energy storage systems, which can benefit the grid, energy users and storage owners alike. Some issues to be resolved include –

- Should energy storage owners who are also customers be considered as two customers (load and generator) or one combined "prosumer" customer?

- Should DSM "megawatt" bids also be included along with storage in-feed?

- What sort of aggregated control of storage is employed to optimise use of stored energy to satisfy various demands, e.g? VPP-type generation bids to the pool, and/or demand reduction to meet grid contingencies and grid/generation capital deferment, and/or ancillary services.

• How should these services be priced and how will the storage owning prosumer make his/her decision - on Power availability or Energy availability or Stand-by capacity? Additionally, if a major drawdown of energy is requested from the storages, forcing recharge during peak/shoulder periods, how can the storage owner are compensated for the higher energy cost, which would otherwise have been avoided?

• It would seem that the storage-owning prosumer should act on a purely "selfish" basis, choosing to provide grid support and/or FCAS or retaining storage to reduce individual peak loads and ToU energy bills, according to prices offered by the NEM generation pool and/or grid owner, as relevant. It does imply that both the ToU tariffs and grid support pricing will have to become much more dynamic and "grid needs" based.

• Finally, is there a role for microgrid structures, wherein local energy storages are factored into micro grid entities that can present themselves to the main rid as controllable loads and dispatchable power sources? Possibly, "virtual microgrids" could be logically set up based on already existing switchable parts of the medium-voltage distribution network. Examples are remote town supplies in far NW Western Australia, and more recently, the (S.A.) Yorke Peninsular Dalrymple North battery, (30 MW/8 MWhr) [14], wherein the local load was deliberately islanded onto the battery storage system as part of the testing routine.

6. CONCLUSION

It can be concluded that energy storage sources are of benefit to both the distribution and transmission grid in two fundamental ways – firstly by reducing peak load and providing standby (“n-1”) and "dispatchable" capacity in the network, and secondly by providing energy capacity for ancillary services such as system inertia and black start capacity. Storage should be located as deep into the network and as close as to the end-user loads as possible. All net benefits then flow upstream to the transmission network and generation assets. The network design and load management strategy should be to optimise net loading at a lowest possible level. Depending on the amount and location of storage capacity, optimisation is done progressively up the feeder system to achieve minimised net loading at the lowest level cluster of load, generation and storage as possible. At this point in time, it will probably be uneconomic to install sufficient storage in the distribution network to provide full “n-1” capacity for failed feeders in the HV sub- and transmission network, although with current battery storage cost trajectories this may well change within the next 10 years.

Modelling of the LV systems shows that there is negligible disadvantage in having only a single energy storage unit for each group of about 30 homes or dwelling units in residential areas, although sizing, location and visual impact constraints in low density residential areas may prevent the deployment of large energy storage units. Storages, if located in each individual house (or small group of a few houses) would be ideal, but should be sized and operated based on averaged and not individual household peak load.

Energy storage location in the transmission system will be more network-specific and dependent on the net (load +/- energy storage charge/discharge) load that would be placed on this part of the network from the distribution system. Detailed load flow analysis is recommended in such cases.

Optimal operation of the charge/discharge regime on each energy storage system could reduce the daily net peak load applied to the distribution network by customer-owners and reduce peak ToU tariff charges. However, in order to realise ancillary/large scale emergency "dispatchable" energy capacity, requiring a minimum level of "on tap" energy storage system charge, some sort of stand-by energy incentive and/or price bidding regime seems to be more appropriate than a simple conventional ToU energy tariff.

7. ACKNOLEDGEMENTS

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A Study of Students' Conceptual Knowledge of Electricity and Magnetism

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Abstract

Over the last several years conceptual surveys have been used to assess students' initial knowledge and misconceptions of various aspects of science and in particular physics and engineering. A study of the conceptual knowledge and common sense understanding of electricity and magnetism was conducted on a group of 40 first year engineering physics students who were intending to pursue electrical engineering studies at the university level to qualify as electrical engineers. A pre-test and a post-test were conducted to ascertain whether there would be a change in their conceptual understanding by adopting interactive methods and online conceptual tutorials on electricity and magnetism. The findings revealed that interactive methods of teaching play a useful role in changing students common sense ideas of phenomena to explaining them in terms of scientific and engineering concepts.

Keywords: Conceptual physics, electricity and magnetism, electrical engineering

1. INTRODUCTION

Most academics are aware of the fact that incoming students enrolling in first year university studies in physics and engineering bring along a baggage of preconceived or non-scientific or common-sense ideas of how physical systems work (Clement, 1982). These alternative conceptions interfere with their understanding of scientific concepts and it takes a conscious effort from academics to change these ideas. The most well-known study of misconceptions in physics (Force Concept Inventory) was the study carried out by Halloun and Hestenes (1985a and 1985b). This has had and continues to have a profound impact on the study of physics and engineering physics worldwide. More recently Mazur (1997) has become a strong advocate of the teaching and learning of conceptual physics. However, there is a difference in the development and use of conceptual surveys in mechanics (Force Concept Inventory) and conceptual surveys in Electricity and Magnetism. The Force Concept Inventory is based on Newtonian mechanics, a well-defined and coherent area of study. In contrast, the development of the Electricity and Magnetism Inventory has a much broader coverage of conceptual areas and as pointed out by Maloney (1985) it relies on "understanding in other domains such as force, motion and energy". The present study was undertaken by the authors to investigate ways and means to reduce the number of students failing the first year Engineering Physics unit in the engineering program and also to improve the retention rate of students studying for the engineering degree. It was also used to investigate their conceptual understanding of electricity and magnetism which is an integral part of the undergraduate degree in electrical engineering.

The survey instrument that was used was based on the Maloney et al. (2001) Conceptual Survey of Electricity and Magnetism (CESM). The areas covered by the survey instrument were the following topics, viz: Charge distribution on conductors/insulators (Q 1,2,13), Coulomb's force law (Q 3,4,5), Electric force and field superposition (Q 6,8,9), Force caused by an electric field (Q10,11,12,15,19,20), Work, electric potential, field and force (11,16,17,18,19,20), Induced charge and electric field (13,14), Magnetic force (Q 21,22,25,27), Magnetic field caused by a current (Q

23,24,26,28), Magnetic field superposition (Q 23,28), Faraday's law (29,30), Newton's third law (4,5,7,24). Maloney, et al (2001) had tested the survey instrument in terms of difficulty and discrimination. Difficulty of 0.5 was taken as the ideal. They defined discrimination as "a measure of how well an item differentiates between competent and less competent students". They also tested their survey instrument for validity and reliability. According to them, "the CSEM is a valid, reliable instrument. The test is a combination of questions probing students' alternative conceptions and questions are more realistically described as measuring students' knowledge aspects of formalism". Twenty questions on electricity and 10 on magnetism were used in this study. We have not attempted to answer all the questions in the survey in this paper.

2. RESPONSE TO THE ELECTRICITY SURVEY

The pre-test was administered in the first lecture in the first week of the semester that the students arrived at the University. The post-test was conducted in the last lecture in the last week of the semester. The pre-test and post-test results are given below. Table 1 gives the results for the electricity component of the survey while Table 2 gives the results for the magnetism component. The analysis of the survey and comments are given after the tables. The total number of students who volunteered to participate in the survey was 40. It was not compulsory for the students to participate in the survey. They came from both government and private schools from the Western Sydney region where the university is located.

Table 1. Results of the correct pre-test and post-test answers to the survey questions on electricity

Questions	Pre-test %	Post-test %	Difference %
1	40	90	50
2	15	90	75
3	10	90	80
4	30	95	45
5	20	95	75
6	40	95	55
7	10	100	90
8	40	95	55
9	35	80	45
10	20	75	35
11	5	80	75
12	20	85	65
13	30	80	50
14	5	80	75
15	10	60	50
16	10	60	50
17	15	80	65
18	10	60	50
19	15	80	65
20	10	55	45

The region has the most diverse community in the Sydney region. They come from various countries around the world. Many of the students are the first in their family to attend a university. For many English is not the first language which is spoken at home. This raises some issues in the study of engineering physics in terms of not fully understanding the material in the textbook. An analysis of the answers provided by the students for the various questions is given below.

2.1. Charge distribution on conductors and insulators (Questions 1, 2 and 13)

The questions were about the distribution of charges on a conducting sphere and a sphere made of insulating material. Students had a vague understanding of the difference between conductors and insulators. They also seemed to be confused about the distribution of charges on conductors and insulators. About 60% of the students answered Question 1 incorrectly stating that the excess charge is evenly distributed over the inside and outside surface of the sphere. The post-test score was 90%. Question 2 was about the distribution of charge on an insulator. 85% of the students got this wrong in their pre-test. A majority of the students wrote that the excess charge is evenly distributed over the inside and outside surfaces of the sphere. 15% gave the correct answer stating that all the excess charge on an insulating sphere remains right around the point P where it was deposited. About 30% of the students gave the correct answer to Question 13 which tested their understanding of the shielding effect of conductors. The post test results for the above questions were well answered. The results were: Question 1 (90%), Question 2 (90%) and Question 13 (80%)

2.2. Coulomb's law (Questions 3, 4 and 5)

Coulomb's law is a fairly straightforward equation to use. However, it was surprising that the students did not do as well as they were expected to do. Only 10% of the students got Question 3 on Coulomb's law correct. However, in the post-test 90% of the students got the question correct. Question 4 (pre-test 30%, post-test 95%) and Question 5 (pre-test 20%, post-test 95 %) had good scores in the post-test. The question was about the effect on the force when the magnitude of the charges and the distances between them were changed. They had difficulty in trying to apply an inverse square law which they were not familiar with in their study of physics and maths at high school.

2.3. Electric force and field superposition (Questions 6, 8 and 9)

Questions on the forces acting on charges and the concept of field superposition could have been better answered in the pre-test. The questions were about finding the effect on the magnitude of the force on a charge in the presence of two other charges. For the pre-test for Question 6, 60% of the students gave the wrong answer. However, in the post-test 95% answered the question correctly. The pre-test for Question 8, was answered correctly by 40% of the students while the post-test was correctly answered by 95% of the students. For Question 9 the percentages of the students who answered the question correctly were: pre-test 35% and post-test 80%.

2.4. Force caused by an electric field (Questions 10, 11, 12, 13, 19, 20)

In question 10 a positive charge was placed at the centre of a region of space in which there was a uniform, three-dimensional electric field. Students were asked to state its subsequent motion. 80% of the students gave the wrong answer by stating that the charge will move with constant velocity with a constant force. Students were still associating constant velocity with a constant force. For question 11, students were asked what happens to the electric potential energy of a positive charge, after the charge was released from rest in the uniform electric field. 5% of the students gave the correct answer by stating that it will decrease because the charge will move in the direction of the electric field. Question 12 which asked students to provide an answer to the electric forces acting on two charges placed at two different positions in a straight line in an electric field received a correct response rate of 20% in the pre-test and a 85% correct response in the post-test. The shielding effect of a charged conducting sphere was not clearly understood by the students. Question 13 stated that a hollow conducting sphere was initially given an evenly distributed positive charge on its surface. They were asked what was the direction of the electric field at the centre of the sphere when a positive charge was brought up near the sphere. In the pre-test only 30% of the students had an understanding of the shielding effect of a conducting sphere. The post-test gave a response rate of 80%. Questions 19 and 20 were not well answered. The pre-test scores were 15 and 10. Students had difficulty in understanding how to find the direction of the electric force exerted on a charged object when placed at two different locations where the lines of equipotential change.

3. RESPONSE TO THE SURVEY ON MAGNETISM

Table 2 shows the results of the survey on magnetism. An analysis of the answers provided by the students for the various questions is given below Table 2.

Table 2. Results of the correct pre-test and post-test answers to the survey questions on magnetism

Questions	Pre-test %	Post-test %	Difference %
21	10%	90%	80
22	15%	80%	65
23	15%	80%	65
24	10%	80%	70
25	20%	60%	40
26	20%	90%	70
27	5%	90%	85
28	30%	90%	60
29	10%	100%	90
30	10%	100%	90

3.1. Magnetic force (Questions 21, 22, 25, 27)

The overall pre-test results for the magnetism survey were rather disappointing. Students either did not answer the questions or gave the wrong answers. In Question 21 students were asked what happens to a positive charge when it is placed at rest in a uniform magnetic field. 10 % of the students gave the correct answer to Question 21, that is the charge remains at rest since the force and the initial velocity are zero. The others said that the charge accelerates in a circle since the force is always perpendicular to the velocity. In Question 22 students were asked in which direction did the magnetic field point when an electron moves horizontally along an arc of a circle towards a screen in front of its direction of movement. 15% gave the correct answer. Students seemed to be confused about the relationship between the direction of the movement of a charge, the magnetic force and the direction of the velocity. Question 25 was answered correctly by 5% of the students. The students were asked to rank the forces acting on positive charges moving in a magnetic field. In Question 27 students were asked to find the resultant magnetic force exerted by two magnets on a stationary charge held between them. Only 5% of the students got this question correct. The post-test answers were much better. 90% of the students gave the correct answer.

3.2. Faraday's law (Questions 29, 30)

Faraday's Law is one of the fundamental laws of electromagnetism. Questions 29 and 30 were used to find out whether students understood Faraday's law and the concept of magnetic induction. 10% of the students got this question correct in the pre-test. 100% of the students got it right in the post-test. Students were not aware that that a moving magnetic field (due to a moving magnet) or a moving coil in a magnetic field will generate an induced current. The post-test showed that 100% of the student's understood this. Question 30 also tested students understanding of the generation of an induced current in a different setting. In this case the loop of wire was moved in different orientations with respect to a long straight wire carrying a large steady current. The pre-test result was 10% while the post-test was 100%.

3.3. Magnetic field caused by a current (Questions 23, 26, 28)

For Question 23, students seemed to have a vague idea of the direction of the magnetic field created by a current flowing in a long straight wire and its interaction with a similar wire close by but with the current going in the opposite direction. The question tested the students understanding of the magnetic field around a current carrying long straight wire. In the pre-test 15% of the students provided the correct answer while in the post-test 80% of the students gave the correct answer. In Question 26 students were given a diagram with a large electric current coming out of the page. They were asked to show the direction of the magnetic field at two points near the wire (one west of the wire and the other north of the wire). In the pre-test 80% of the students gave the wrong answer. They found it difficult to indicate the direction of the field. In Question 28 the students were given a diagram which showed two wire loops (one above the other) carrying identical currents moving in anti-clockwise directions. They were asked to indicate the correct direction of the magnetic field at a point midway between the loops. In the pre-test 30% of the students gave the correct answer. The post-test result was 90%.

3.4. Newton's third law (Questions 7 and 24)

Students were not aware that Newton's third law also extends to the domain of electric and magnetic phenomena. This was experienced in Questions 7 and 24. For Question 7, 10% of the students gave a Newtonian response. However, a larger number of students stated that the larger magnitude charge exerted a larger force. In Question 24, 10 % of the students answered the question in Newtonian terms. The rest thought that the larger current provided a larger force on the other wire. In his study of electricity and magnetism in Israel, Galili (1995) found that many students were not aware that Newton's third law also applied to the study of electromagnetism. Students also had difficulties applying the concepts of work and energy in contexts which involved electric and magnetic fields (Saglam and Millar, 2006).

4. COMMENTS AND SOLUTION

Overall the pre-test scores were rather disappointing. It was probably due to the lack of familiarity with the phenomena associated with electricity and magnetism and also to the formalism of the subject. The phenomena is not familiar to the students in their daily life. It has to be experienced in the laboratory using scientific equipment. Furthermore, they had difficulty in visualizing two dimensional representations in three dimensional form. The Electricity and Magnetism survey is in sharp contrast to the Force Concept Survey which deals with situations that are more familiar to students in their daily lives. It has also to do with the teaching style adopted in schools. In the interviews conducted with the students the researchers were informed that in many cases they took down lots of notes in class rather than being exposed to experiments on the topics of electricity and magnetism.

Another major reason is due to the content of the Higher School Certificate physics curriculum that was adopted by the New South Wales Education Standards Authority. Since 2001 the physics syllabus was watered down. It is less mathematical and includes topics on the nature and history of science and an emphasis on writing essays on the social dimensions of science or physics. The reason for the introduction of the 2001 curriculum was to entice more students to study physics at the Higher School Certificate level without realising the impact it would have on the teaching and learning of physics at the university level. The content includes 'Prescribed Focus Areas', such as Moving About, From Ideas to Implementation and separate 'Option' topics (e.g. medical physics, geophysics and electronics). The topics included a broad range of content which included: Equations of motion, Specific scientific breakthroughs, and Social issues. This has meant that while Newton's Laws on Motion are taught, unfortunately electricity and magnetism were taught in a cursory manner in electronics. Because of the criticism from the physics and engineering communities over the last few years hopefully a new syllabus will be introduced in 2019. The new syllabus is to have an increased mathematical content and a reduced emphasis on the social dimensions of science. The new topics will include classical physics (waves, mechanics, electricity, magnetism and thermodynamics). One of the other problems as to why students received low grades in the pre-test has to do with the quality of the teachers who are teaching physics in schools. According to Georgiou and Crook (2017), "one in five science teachers are not technically qualified to teach science and 40% of schools report that they have difficulty filling maths and science teaching positions".

In order to reduce the failure rate of students studying engineering physics at the university, it was decided to introduce interactive methods of teaching for the laboratory experiments, the tutorials and the delivery of lectures. Rather than delivering a monologue of the physics content in the lectures, the lecturers adopted a Question and Answer style of delivering the content. The lectures were structured in such a way that the theory was explained for about 10-15 minutes followed by 10 minutes of Q & A and solving problems in lectures. This method was adopted throughout the three hours lecture. This allowed students to be more attentive in the lectures and it allowed the lecturers to find out whether they had understood the theory and so get immediate feedback from the lecturer. The choice of the textbook also played an important role in ensuring students grasped the conceptual aspects of the theory under discussion. The textbook that was used was the first Australian edition of University Physics with Modern Physics written by Young, Freedman and Bhathal (2011). The strength of the textbook lay not only in the conceptual way that the topics were discussed but also the online 24 hour electronic tutorial system which came with the book. This allowed students to do their tutorials at a time that was convenient to them. Many of the students studying engineering physics had casual jobs to support their studies at the university. This flexibility was very much appreciated by the students. If they had any difficulties they could see the lecturers for a face-to-face meeting. The labs were compulsory. Students had access to a short video of what the experiment for the week was about before they came to the lab. Students also had to complete 3 or 4 questions pertaining to the experiment before they came to the laboratory to do the experiment. Simple props built in the engineering workshop were used to demonstrate the principles of engineering physics in the lectures. A randomly selected student or students were asked to perform the demonstrations in front of the class. This was very popular with the students as it involved them in an active learning environment. By using an interactive learning environment it was possible to reduce the failure rate from about 40% to less than 12% over a couple of years. It is our goal to reduce the failure rate to less than 10% without sacrificing the quality of the engineering physics program.

5. ACKNOWLEDGEMENT

We wish to acknowledge the use of the excellent electricity and magnetism survey developed by Maloney et al. (2001) for investigating the conceptual knowledge and the baggage of common-sense ideas that students brought to the engineering physics class. It provided an incentive to the academics to introduce more interactive and hands-on methods in the teaching and learning of engineering physics.

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An Innovated Three-Step Teaching and Learning Approach for Laboratory Experiments of Thermal Fluids Courses

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Abstract

The teaching and learning of thermal fluids courses are always challenging due to its complex and abstract nature, and the mathematics involved. With diminishing resources (continuous funding cut, frequent professional/academic staff career movement, lack of competent professional staff, inadequate laboratory infrastructures, teaching and learning thermal fluid courses become harder. It is progressively becoming difficult to teach thermal fluids courses effectively. As a result, students cannot achieve effective learning outcomes. To overcome these challenges, a three-step teaching approach has been developed to enhance students' learning outcomes. This approach is cost effective, user-friendly and attractive. The method comprises a real laboratory video clip, conduction of a real laboratory experiment and a computer simulation/modelling. The developed three-step teaching and learning approach can be applied to not only thermal fluids courses but also other courses.

Keywords: Teaching & learning, thermal fluid course, laboratory experiment, CFD.

1. INTRODUCTION

Laboratory practices have been an essential part of engineering curricula from the earliest days of engineering education in order to prepare students to practice engineering (i.e., dealing with materials, energy and information) thereby creating benefit for humankind. However, the emphasis on laboratory practices has varied over the years as much attention has been put on curriculum and teaching methods and relatively little effort has been put on laboratory practices as noted by Feisel and Rosa (2005), Alam et al. (2007) and Alam et al. (2004). Funding constraints (diminishing resources) and lack of consensus on the basic objectives of the laboratory practices are the main reasons for inadequate laboratory development and scant research on education of laboratory practices. While there seems to be general agreement that laboratories are necessary in engineering education, little has been undertaken to accomplish it as noted by Feisel and Rosa (2005), Alam et al. (2007) and Alam et al. (2004). There are generally three basic types of engineering laboratory practices: a) development, b) research, and c) educational (Feisel and Rosa, 2005). While a development laboratory is intended to answer specific questions of immediate importance, research laboratories are used to seek broader knowledge that can be generalised and systematized, often without any specific use in mind. The output of a research laboratory is generally an addition to the overall knowledge. Educational laboratory practices especially for undergraduates where students do not generally extract some data necessary for a design, to evaluate a new device, or to discover a new addition to our knowledge of the world. Each of these functions involves determining something that no one else knows or at least that is not generally available. Students, on the other hand, go to an educational laboratory to learn something that practicing engineers are assumed to already know (Feisel and Rosa, 2005; Alam et al., 2007 and Alam et al., 2004).

Most engineering programs especially mechanical and civil engineering need hands-on workshop facilities for running educational laboratory practices to achieve academic objectives (Alam et al.,

2007) and Alam et al., 2004). Industries and research organisations want to have graduates equipped with hands-on practical and theoretical knowledge who are ready for immediate work assignment without even undergoing induction training. This is why the professional bodies of the Washington Accord signatory nations have put special emphasis on the Stage 1 Competencies for accredited Bachelor of Engineering programs. For example, Engineers Australia's 2.2 & 2.3 of Stage 1 Competencies and Hong Kong Institution of Engineers' B of Stage 1 Competencies are dedicated for educational laboratory practices (i.e., students must develop an ability to design and conduct experiments as well as to analyse and interpret data). In order to achieve this objective, engineering educational institutions/ universities are required to invest and develop engineering workshops and practical laboratory facilities to equip students with both theoretical as well as hands on practical knowledge as per the workplace demands.

With continuous funding cuts and diversion of resources to other areas, even the developed nations' engineering educational institutions are struggling to invest in new laboratory facilities and maintain existing facilities to educate students with the required technical, real world, hands-on knowledge and skills. Due to financial hardships, the educational institutions in developing countries have less laboratory facilities than their counterparts in developed world. Mechanical and civil engineering programs are hit hard. Many mechanical and civil engineering departments are forced to reduce their expenditures on new laboratory equipment, refurbishment of old laboratory facilities/equipment, operation and maintenance costs, and supporting technical and academic faculty members (Alam et al., 2007; Alam et al., 2014a&b; Rahman and Al Amin, 2015; Rahman, 2017 and Lemckert, 2003). As the class size is progressively increasing, the conduction of laboratory practices education becomes harder. To reduce operation cost, most universities/institutions increase the class size (in some cases over 300 students). For educational laboratory practice, a large class needs to divide into numerous sub-groups with the number of students less than 10 (Alam et al., 2007; Alam et al., 2004 and Morishita et al., 2000). Due to time, space and equipment constraint, it is extremely difficult to accommodate and run laboratory practice sessions for large number of sub-groups. In western universities, usually, postgraduate (PhD & Masters) students supervise and conduct laboratory experiments for undergraduate students. This practice requires running induction and training sessions for the laboratory assistants. Once, these laboratory assistants become well trained and experienced, they need to leave after the completion of their programs (Masters and PhD). Therefore, the subject coordinators need to start all over again from the start to train newly commencing postgraduate students who can supervise and conduct laboratory practices for undergraduate students.

2. A THREE STEP TEACHING AND LEARNING APPROACH

To provide students an opportunity to conduct hands-on laboratory practices under the supervision of an experienced laboratory assistant within a reasonable time, a three-step laboratory teaching methodology has been developed in the School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University. The three-step approach comprises: a) a video clip of the real laboratory experiment by an experienced faculty member/academic staff, b) hands-on conduction of the laboratory practice by students, and c) computer simulation using Computational Fluid Dynamics (CFD) software and validation of modelling data utilising the real experimental data.

2.1. Video Clip of the Real Laboratory Experiment

A video clip was made of real experiment by an experienced academic staff/faculty member that explains all the relevant theoretical knowledge required for the hands-on laboratory experiment and description of all equipment as well as how to use them. All students are required to watch the video clip before they carry out the real laboratory experiment at their own time and pace from any location via online. As students become familiarised with the laboratory equipment, facilities, relevant theories and occupational health and safety issues well before they undertake the actual laboratory work, the duration of actual laboratory practice time is shortened to one hour from one and half to two hours.

The time reduction did not compromise the quality of laboratory practice education. Moreover, it helped to reduce operational and supporting technical time plus other logistic costs. The reduction of time one hour helped to fit more groups within set time frame thereby reducing the groups' que and allowing to provide quicker feedback to students on their submitted laboratory practice reports. Students are allowed to proceed to step two (conduction of laboratory practice) after passing an online quiz on step one. If any student fails the quiz, he or she needs to retake the quiz until passes. Each attempt will have different set of questions. After successful completion of step 1, students are allowed to commence step 2 activities in a group. A laboratory practice on drag measurement of a circular cylinder is used as real experimental work. This laboratory work is common for mechanical, automotive and manufacturing, aerospace engineering programs as part of thermal fluid mechanics course. Some civil engineering program also includes this course.

Figure 1: A video clip of a real laboratory practice demonstration

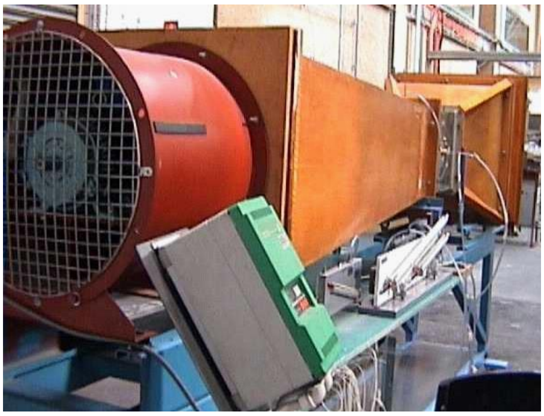


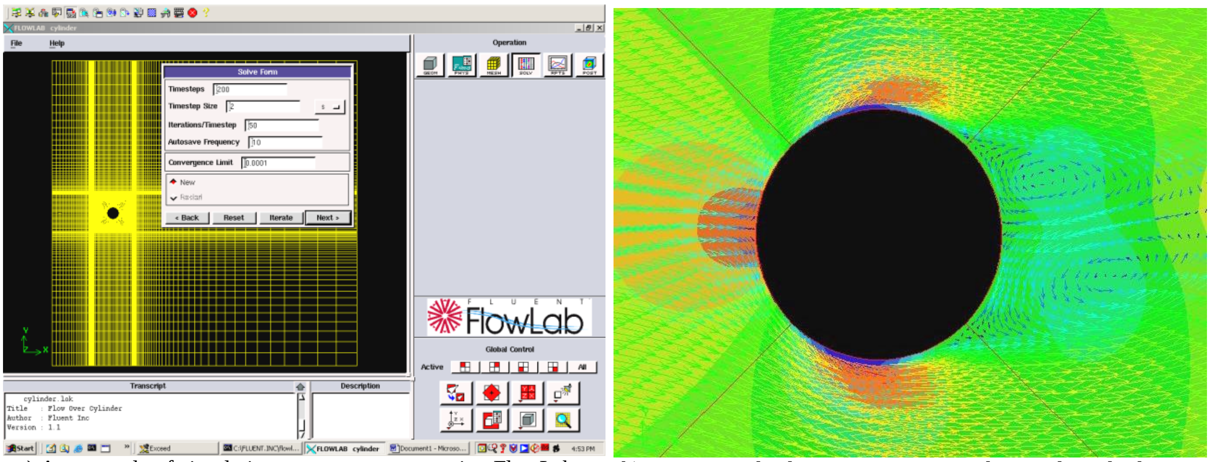
Figure 2: A Physical Laboratory Experiment Set Up (Portable Wind Tunnel)

2.2. Hands-on Conduction of the Laboratory Practice

The real laboratory experiment on the drag measurement of a circular cylinder is conducted using a portable wind tunnel. The School of Aerospace, Mechanical and Manufacturing Engineering possesses several portable wind tunnels. One of these wind tunnels is shown in Figure 1. It has a square test section of nominal size: 300 mm width x 300 mm height x 500 mm length. Flow is drawn through the tunnel by an axial fan located at the tunnel's exit (see Figure 2). A circular cylinder with a traversing mechanism is mounted in the test section. A Pitot-static tube is mounted on a traversing gear that can move vertically up and down so as to measure the local value of velocity behind the cylinder. For the experiment, in addition to the wind tunnel with a probe traversing mechanism, a circular cylinder with a tiny hole and a protractor, a Pitot static tube with flexible plastic tubing, a manometer, a thermometer and barometer (to measure the ambient temperature and pressure, respectively) are required. The experimental procedures, parameters to be measured, relevant theory and sample calculations are provided on the Web site for the Virtual Laboratory Video.

2.3. Computer Simulation

After the conduction of real laboratory experiment, students undertake a 2D simulation using FlowLab and learn a fundamental process of CFD simulations by simply selecting different sets of the following: cylinder radius, mesh, physical conditions, iterating parameters of the solver, reporting and post-processing. For example, regarding the pressure coefficients (Cp), students can change the size of the cylinder radius, velocity, etc., and find out the effects of these through plots of pressure distribution and pressure coefficients along the surface of the cylinder in order to understand flow behaviour under different physical conditions. Furthermore, students can select different sets of numerical schemes, such as discretisation schemes and underrelax factors, so that they can perceive more clearly how numerical methods impact on the results of CFD simulations and understand how important a role it can play. An example of a CFD set-up and derived results using FlowLab are shown in Figure 3. CFD learning enhances students' physical understanding of the experimental system, which can be hard to attain from a few point measurements and can give an impression that modelling involves approximations and tradeoffs, the confirmation of some aspects of the data processing for the experiment (e.g., that a mixing region is long enough) and confirmation of experiment and correlation.



a) An example of simulation parameter set-up using FlowLab b) Pressure and velocity contours around a circular cylinder

Figure 3: Computational modelling input screen and results

3. PILOT STUDY AND IMPLEMENTATION

A group of 20 students was selected for the pilot trial of the three-step laboratory teaching method. The participation of students was entirely voluntary. All student participants had gone through all three steps. They watched the video clip first, then conducted the real laboratory experiment and simulated the same laboratory conditions using Computational Fluid Dynamics (CFD)/FlowLab on a computer. Students analysed the data obtained from experimental and CFD simulation and compared them. Later, they modified the simulation variables in order to acquire further knowledge. Finally, the students submitted a comprehensive laboratory report. Selected students were given a set of survey questions to evaluate their impression of the three-step teaching concept to obtain feedback. Primary survey questions are shown in Alam et al., 2007.

The survey was structured to gain insight into students' perception regarding the following concerns: the laboratory instructional video clip; experimental module effectiveness; effectiveness of CFD to reinforce concepts introduced by experimental work; and relevance of the actual laboratory practice and CFD components of the course. A general comments section, designed to capture additional student feedback, was also included in the survey. The analysed data of students' perception is shown in Figure 4.

The students feedback showed a great satisfaction on three step teaching and learning of laboratory experiment. The student's performance varies notable between the group of students who took part in pilot study and who did not take part in the study. The students who completed all three steps of the method performed better and the quality of their lab reports reflected it well.

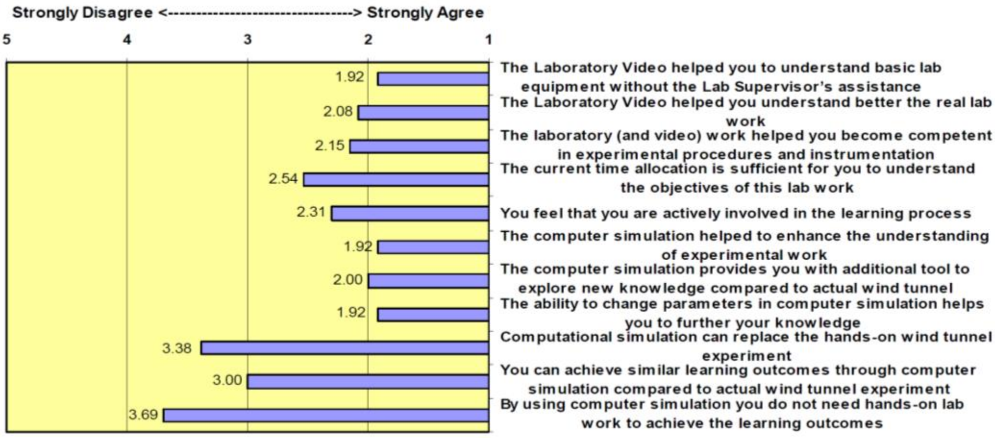


Figure 4: Students' feedback: descriptive statistics

4. DISCUSSION

Engineering educational institutions are progressively introducing computer aided learning packages as an alternative to hands-on practical laboratories and field experiments. Hands-on practical laboratories help students to understand complex theoretical problems and apply theoretical knowledge in practice as noted by Feisel & Rosa, 2005; Alam et al., 2007 and Alam et al., 2004). However, there are some mechanisms or phenomena that are difficult to visualise due to technical constraints and/or operational safety reasons. Thanks to the tremendous progress in computational power over the last decade, these complex and difficult phenomena can now be visualised with the help of powerful computational tools as noted by Gibbins & Perkin, 2013 and Alam et al., 2014a&b. However, a virtual laboratory cannot be a replacement of real laboratory as many laboratory works cannot be accurately simulated and students may not be able to get a real feel that hands-on practical experience can offer. Hands-on experience is a necessary requirement to tackle real world engineering problems effectively. Therefore, both hands-on laboratory experiments, computer-based simulations and web-based visualisation are required. However, a balance between simulation and practical work is also required to provide students with an appropriate level of simulated and hands-on laboratory experience. To the authors' knowledge, no studies on the appropriate balance between simulation and practical works have been reported in the open literature.

The three-step laboratory teaching approach was pilot-tested in order to obtain students' feedback and to check whether it helps students to achieve the desired learning outcomes in a relatively difficult subject in a mechanical engineering program. In aerospace, mechanical, manufacturing and automotive engineering programs, fluid mechanics is one of the common subjects for undergraduate students. Fluid mechanics is generally considered as one of the most complex and challenging subjects as it deals with the complex nature of mass flow and heat transfer, and the basic concepts are usually difficult to understand due to the level of mathematics and physics required.

5. CONCLUDING REMARKS

The three step teaching and learning approach enhances students learning outcomes. It has now been used for undergraduate mechanical and automotive engineering students' thermal fluid mechanics courses at RMIT University.

The approach is especially useful for large class size as it allows shortening the time of physical conduction of laboratory experiment to 1 hour.

The method can easily be used for other programs such as aerospace and civil engineering programs.

The developed three step teaching and learning approach is sustainable and cost effective, as it should not require any ongoing costs – except some minor maintenance cost of physical equipment.

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Challenges in Teaching Environmental Engineering: A Case Study in Australia

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Abstract

Water is one of the most vital substances for all living creatures on earth. Access to safe water is the primary requirement for survival of human being. Water pollution is caused by multitude of factors including both natural and anthropogenic ones. To build a sustainable world, water/wastewater needs to be well managed and in many cases need to be treated to remove the undesirable pollutants before human consumption or release to natural environment. To that end, water and wastewater treatment is regarded as an important subject in the study of engineering. Subjects related to wastewater treatment are taught in Civil, Chemical and Environmental Engineering at undergraduate level in Australia which requires fundamental understanding of Biology, Chemistry, Physics and Mathematics. It is incredible to see that many of the undergraduate students who have completed their higher secondary studies from different Australian high schools and enrolled in these engineering courses at various universities do not have sufficient prerequisite knowledge on these subjects. As a result, they often struggle to learn the concepts and science involved in the water and wastewater treatment process. This paper highlights and discusses the level of knowledge required to understand water and wastewater treatment processes. It also proposes a strategy which could be useful to struggling students in grasping the concept of water and wastewater treatment processes.

Keywords: Water, Wastewater, Treatment, Education, Environmental engineering, Sustainability

1. INTRODUCTION

Till 1960s there was little regard to environment, and there was hardly any undergraduate degree on environmental engineering or science at the tertiary level. People mostly invested and focused on the development of transportation, industrial machinery and infrastructure. Pollution was not a topic for consideration either at government and society level. Over the last few decades, high rate of population and technological developments resulted in pollution of air, water and soil at many locations around the globe. The green movements during 1960's to 1880's created a positive environmental awareness, which resulted in the need of the in-depth environment studies. This created opening of new disciplines such as Environmental Science and Environmental Engineering at tertiary levels. Water and wastewater treatment is one of the major issues in these disciplines of study. Since the world population will continue to grow, wastewater management in cities, rural and urban areas has to be taken seriously into consideration to build a sustainable environment.

The fundamental subjects that are required to complete a Bachelor Degree in Environmental Engineering at the universities of western countries are English, Biology, Chemistry, Mathematics and Physics. It is expected that the students have firm understanding on the basic topics of these subjects and they can apply what they have learned to real world problems. However, in many developed countries including United States of America (USA) and Australia students are not learning the content and skills in the science, technology, engineering, and mathematics (STEM) subjects that could help them in succeeding in this highly competitive era of science and technology (Hofstein & Lunetta, 2004). Moreover, many students feel that science and mathematics are not for them. This is not because they are not interested in science rather the method of teaching these subjects, cultural and peer issues. The exercise of memorization and regurgitation is still the way of studying science for most of the students even in USA (Powell & Anderson, 2002). Furthermore, there are number of reports suggesting reforming the curriculums for science and mathematics education (Yager, 1992). In 1984, Bybee et al. (1984) reviewed a range of national reports on science education in USA and argued that the traditional practice of science and technology needs to be restructured which should have more focus on integrating science-technology-society themes, problems, and issues. Recently, USA has reformed its science education, which is directed at integrating STEM (Hoeg & Bencze, 2017). The advantages of STEM education include creation of the knowledge and skills that are helpful in creating new jobs and participation in the societal needs (Rennie et al., 2013).

The declining standards of STEM Australian schools directly flow into the quality of students entering into engineering courses. Recent statistics demonstrate that Australia is facing a crisis in the standards of STEM education in her schools, e.g. approximately 40 percent of mathematic classes in years 7-10 are taught by a teachers unqualified in mathematics and the number of students choosing “science” subjects in schools are the lowest they have ever been in 20 years, with Physics being studied by only 14 percent of students in 2010 (Chief Scientist, 2014a). The aim of this study is to present an overview of the current scenario of the background knowledge of the students enrolling into the Environmental Engineering course at Australia universities. This also proposes a solution how struggling students in the Environmental Engineering course in university can be supported.

2. NEW SOUTH WALES SCHOOL CURRICULUM FOR HIGHER SCHOOL CERTIFICATE

To get the Higher School Certificate (HSC), 12 units of preliminary courses and 10 units of HSC courses need to be successfully completed. Preliminary courses require to be completed prior to start corresponding HSC courses. There are two main types of HSC courses, which are Board Developed Courses and Board Endorsed Courses. There are 140 Board Developed Courses. In these courses, 105 examinable courses, 13 industry curriculum frame work and 27 life skills courses for students with special education needs. Board Developed Courses cover English, Mathematics, Science, Technology, Creative Arts, Personal Development, Human Society and its Environment, Languages, Vocational Education and Training (NSW Education Standard, 2018).

3. DISSOCIATION BETWEEN HSC AND UNIVERSITY UNDERGRADUATE ENROLLED COURSES

In 2018, 76,732 students are studying in one or more HSC courses in NSW (HSC Students Overview, 2018). **Table 1** represents the subjects and the corresponding enrollments. As can be seen, English, Mathematics, Physics, Chemistry and Biology are in the top 15 enrolled subjects. These are potential subjects which are required in Environmental Engineering courses (HSC Course Enrolments, 2018). It is noticeable that a higher number of students are enrolled in English (91.40%) and Mathematics (76.40%), while the enrolments are much lower in Physics (12.89%), Chemistry (14.72%) and Biology (23.93%). **Table 1** also indicates that not all students who have enrolled in Mathematics have enrolled in Chemistry, Biology and Physics (HSC Students Overview, 2018).

Table 1 HSC subjects and the related enrolments in NSW (HSC Students Overview, 2018).

#	Subject	Unique enrolments	Percentage
1.	English	70136	91.40
2.	Mathematics	58624	76.40
3.	Biology	18361	23.93
4.	Business Studies	18093	23.58
5.	Personal Development, Health & Physical Education	17399	22.68
6.	Studies of Religion	14748	19.22
7.	Modern History	11349	14.79
8.	Chemistry	11295	14.72
9.	Legal Studies	10606	13.82
10.	Physics	9586	12.49

Table 2 Subject wise enrolments in 2018 in NSW (HSC Course Enrolments, 2018).

Course name	Units	Male	Male (%)	Female	Female (%)	Total	Percentage
English (Standard)*	2	15748	51	15363	49	31111	40.55
English (Advanced)	2	10887	41	15398	59	26285	34.26
English as a Second Language	2	1088	46	1259	54	2347	3.06
English Extension 1	1	1285	31	2831	66	4116	5.36
English Extension 2	1	426	28	1112	72	1538	2.00
English Studies	2	5132	59	3566	41	8698	11.34
Mathematics General 2	2	15595	49	15968	51	31563	41.13
Mathematics General 2	2	15595	49	15968	51	31563	41.13
Mathematics*	2	9578	53	8549	47	18127	23.62
Mathematics Extension 1*	2	5293	57	3916	43	9209	12.00
Mathematics Extension 2	2	2054	64	1168	36	3222	4.20
Mathematics General 1	2	2411	61	1512	39	3923	5.11
Biology	2	6856	37	11505	63	18361	23.93
Chemistry*	2	6046	54	5249	46	11295	14.72
Earth and Environmental Science	2	818	51	772	49	1590	2.07
Physics*	2	7265	76	2321	24	9586	12.49
Senior Science	2	3566	53	3172	47	6738	8.78
Design and Technology	2	1872	56	1472	44	3344	4.36
Engineering Studies	2	1893	93	150	7	2043	2.66
Industrial Technology	2	4952	85	868	15	5820	7.58
Information Processes and Technology	2	2076	81	485	19	2561	3.34%

Table 2 (HSC Course Enrolments, 2018) indicates the percentage of students enrolled in 2018 in individual subjects. The [*] marked units are assumed to be required for undergraduate environmental

engineering courses. It is noticeable that around 41% students enrolled English standard and Mathematics general. According to authors understanding, even though other subjects would be helpful for Environmental Engineering courses, these four subjects are the most important. The rest of the subjects are beneficial if they completed in the HSC but very few students have enrolled in these subjects.

Table 3 includes subject requirements to enroll in Environmental Engineering courses at Australian universities. As can be seen, not all the fundamental science subjects are pre-requisite to enroll in Environmental Engineering related courses. Universities assume that the students have completed Mathematics Extension 1, Physics and Chemistry from high school. Because of this assumption any science student who has completed Mathematics with the combination of either Mathematics Extension 1 or Physics or Chemistry or Biology are eligible to apply in this course if they meet the required ATAR score. As a result, some students who did not complete all those four subjects in HSC struggle to pass or getting good grades in Environmental Engineering courses at the universities. In order to help these students the respective teacher has to offer bridging courses for them or provide other supports. Because of the difficulty faced by many students, they drop out from these courses. In many cases, teachers are unjustly blamed for students leaving this course. It should be noted Australian engineering courses have a dropt our rate of over 20%.

Table 3 Courses to study environmental (water/waste water treatment) engineering in the Universities.

University	Course name	Department	Perquisite course	Assumed knowledge	ATAR requirements
University of Sydney	Bachelor of Engineering Honours (Chemical And Biomolecular)	Chemical Engineering	Mathematics (Band 4).	SC Mathematics Extension 1, Chemistry	87.05-92.00
University of New South Wales		Civil Engineering		HSC Mathematics Extension 1, Physics.	
University Technology Sydney		Civil and Environmental Engineering		HSC Mathematics Extension 1; Physics; and English (Standard).	77-92
Western Sydney University		School of Computing, Engineering and Mathematics		Two units of Science, two units of English and Mathematics (not General Mathematics) at Band 5 or higher.	90

Figure 1 represents the enrolment trends in math and science subjects at Australian high schools for last 20 years. As can be seen, the enrolment in science subjects is declining at an alarming rate. The data was published in one of the reports by Australian Chief Scientist. Students are more likely to choose subjects that have direct relation to job market. For example, in Australia, engineers have more job opportunities than physicists. Therefore, the enrolment in engineering education is much higher than physics which ultimately reduces the number of experts in this area. Hence, science subjects such as, physics, mathematics, chemistry and biology are taught by out of field teachers in school, college and universities. When these students enroll in environmental engineering course, they often struggle to understand basic chemistry and physics related problems. The third author of this paper offered Environmental Engineering course in Western Sydney University for over five years and he found students with no chemistry background and he has to teach them very basic chemistry such as symbols, chemical reactions and mass balance. These students either fail the course or needed extra support.

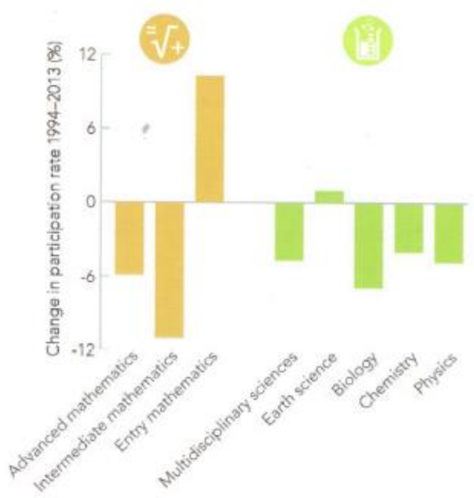

Figure 1 Enrolment trends in Australian high schools

NSW Schools are suffering from shortage of qualified teachers to teach STEM subjects. For example, of the 46,970 teachers employed by the Department of Education in March 2015, only 1,219 were specialist maths teachers compared with 4,079 English teachers. Maths teachers are the third smallest group. One in five science teachers are not qualified to teach science, and some 40% of schools have difficulty in finding maths and science teachers. This presents an overall decline in Australia's standard of STEM education.

4. POSSIBLE SOLUTION

The world is getting more and more competitive with the development of advance technologies. To survive in this competition, Australia must have an education system that matches with its peer countries. For example, the educational system in South Korea, Singapore, Japan and European countries are quite advanced in preparing school students for engineering education. Higher secondary/college students from those countries have to study mathematics and science subjects (e.g. physics and chemistry) at advanced level to get admission into engineering programs at the universities.

The following measures can be taken at the university level to address the current issues of poor science background:

- ✓ Identify and offer help to the students who are struggling by offering short courses to the

students to enhance their background knowledge and skills.
- ✓ Recommend students to complete basic science courses from Science Faculty before enrolling into the courses that require specialist knowledge such as chemistry for studying wastewater treatment.
- ✓ Amend the selection criteria for the future students relevant to Environmental Engineering courses and do not accept students who do not meet the background knowledge or send the students to WSU College or similar colleges under the university to complete a preparatory course on mathematics and sciences.

With the technological development, university courses are being taught using variety of innovative techniques such as online and blended learning. Based on the online proportion of the course delivery at the tertiary level, there are four categories of course delivery (Bourne et al., 2005; Allen et al., 2011):

- ✓ Traditional: zero percent online course contents
- ✓ Web based: 1%-29% of the course contents are given in online
- ✓ Blended/Hybrid: 30%-79% course materials are given to students through online
- ✓ Online: 80%-100% course materials are available in online.

Among the above methods, blended learning approach is considered to be an effective one as it offers greater flexibility and takes advantages of both the face to face and online delivery methods, which can easily meet students' expected learning needs (Rahman, 2017). It is important to inform the HSC students about the prerequisite subjects prior to enrolling into any course especially engineering courses. It seems many students are unaware about the strong background knowledge needed to study engineering subjects.

5. CONCLUSION

This paper represents an overview of the current scenario of NSW education system for STEM subjects. We have found that fewer students are enrolling in science subjects and many of the STEM teachers at HSC level are out of field in NSW. The Australian universities do not have specific requirements to enroll in an engineering degree. As a result, many of the students enroll into the engineering courses without having basic understanding in physics and chemistry. Specialist subjects such as water and wastewater treatment needs a high level of chemistry knowledge, which is often lacking in HSC graduates. . STEM education is a long-term process, which starts in early childhood education, continues through the school education and extends into tertiary education where it is used greatly. Australia needs a complete overhaul of its STEM education in schools. The situation will decline with time unless it is taken seriously.

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Water Education in Australian Schools: A Case Study in New South Wales

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Abstract

Water is a vital source of life. In developed countries, we are extremely fortunate to be able to access water at our fingertips, with little cost. Consequently, our water use is so much, that per capita, per day water demand in Sydney is about 303 litres. In contrast, about 1 billion of the world's population does not have access to as little as 5 litres of safe drinking water per day. Access to safe drinking water is regarded as a basic human right, but to our surprise, about one-fifth of the world population does not have access to safe drinking water. Water is also an integral part of the ecosystem. Educating our school students about water is important so that this precious resource is preserved and enhanced for all the human beings. This paper presents an overview of water education in New South Wales. It has been found that New South Wales school children receive basic education on water such as learning about the hydrologic cycle and water recycling, but limited mathematical aspects of water management are covered. Due to climate change, increasing water demand and increasing pollution, water accessibility will be a challenging issue in the near future. Water education will assist to achieve sustainable water development in Australia.

Keywords: Water, school education, water education, teaching, learning, NSW

1. INTRODUCTION

Water is one of the most important resources for our survival on this planet. It is directly consumed by human beings and is the cornerstone of sustainable development. Water is also used in recreational activities and majority of our food production directly depends on water. To manage water resources, we need to educate the population at different levels. We need water experts who can treat, transport and reserve water for us. At the same time, a layman person needs to know how to save water. In many parts of the world, a person has to travel long distances to access drinking water. On top of this, many people in the world do not have access to clean drinking water, which hinders their growth and undermines their quality of life.

Water is linked with many different disciplines of knowledge (Rahman et al., 2018). Water education starts from early childhood at the household level, e.g. distinguishing clean water from contaminated water, washing hands with clean water before consuming food and turning off taps when they are not needed. School children learn water science in many different subjects. In universities, there are subjects that teach water science or engineering at a greater depth to produce water experts. These water experts manage water resources in a country and their typical jobs include providing clean drinking water, flood management, irrigation project management, wastewater treatment, cleaning rivers and bays and water recycling and conservation. A water expert requires diverse knowledge often encompassing multiple disciplines such as mathematics, physics, chemistry, biology, economics and sociology. They often study specialist subjects such as fluid mechanics, hydraulics, hydrology, water treatment, fluid dynamics and water resources management. Due to the intrinsic relationship of water with the environment, water has been made as a subject of study in many disciplines of knowledge (Grimmond, 2010).

This paper presents an overview of water education in Australia. It presents general aspects of water which is followed by an overview of grand water challenges, importance of water education and an overview of water education in NSW schools.

2. WATER: ORIGIN, COMPOSITION, MYTHS AND IMPORTANCE

Water has been an integral part of every facet of society. It has presented itself from religious texts to agriculture and urban planning. The various stories of water indicate the long standing curiosity and affinity humans have had with water. As noted by Biswas (1970), the history of mankind can be written in terms of human interactions and interrelations with water.

Throughout the ages, water has permeated into the stories, legends and myths of cultures around the world; Scottish mythology describes a translucent water creature that is mistaken for ghosts. Scandinavian folklore claims the existence of a horse that would lurk near rivers during foggy weather. If anyone tried to ride the horse, the horse would jump into a river and drown their rider who would be trapped and unable to separate itself from the horse. Aboriginal stories talk about an evil spirit, the Bunyip who lived in water area, eating humans and spreading disease through water. Dragon Kings from Chinese mythology ruled over the four seas of of China. From the Kraken, Jengy, Grindylows and Leviathan - creatures of the water are myriad. Just as many stories exist about creatures of water, there are legends where water plays a significant part in the story, such as the River Styx which granted invincibility to Achillies' entire body, excluding his heels. This became his eventual downfall when an arrow was shot into his heels, or the story of Manu from Hindu mythology, who survives a flood when he finds a fish in the form of a God in the river.

Stories of the past show the fascination humans have always had with water. As science progressed, the knowledge and importance of water progressed also. It is almost common knowledge now, that water is essential for human survival whereby humans would be unable to survive without drinking water for up to 3-5 days. Water makes up about 60% of the human body. It is required in the transport of nutrients to cells and maintaining the blood volume for healthy functioning of the heart. It is also common knowledge that water is composed of hydrogen and oxygen molecules in the ratio of 2:1, respectively. Humans have discovered what exactly water is with regards to its chemical composition, however fascinating questions still remain - water is recycled on Earth, but where exactly does water come from, how did it first come to Earth? Why has water only been found on Earth and not in our neighbouring planets?

3. GRAND ISSUES IN WATER MANAGEMENT

The biggest issue in water management is supplying drinking water to millions of people in developing countries. More than 1.2 billion people lack access to clean drinking water out of 7.2 billion people (i.e. about 17% of people living in the world). This is equivalent to 40 times the current Australian population. It is surprising that even in this age of superior technology, we are unable to serve 1.2 billion of our fellow human beings with as little as 5 litres of clean drinking water. Our scientific community and world leaders should take this as one of their gross failures.

The second biggest challenge surrounding water management is the death and damage caused due to flooding. For example, in 2017 alone, flood damage in USA was worth approximately US$ 60.7 billion. Due to climate change, flood severity and damage will increase in near future. In Australia, between 1852 and 2011, at least 951 people were killed by floods and another 1326 were injured.

The third biggest water related challenge is lack of water for agricultural use i.e. drought. This costs billions of dollars of damage worldwide every year. Most droughts are followed by famine, deaths and displacement.

Another challenge is how to provide clean water to war displaced people who live in camps, where there is little infrastructure for the provision of drinking water.

Ban Ki-moon, Former UN Secretary General stated “Over the coming decades, feeding a growing global population and ensuring food and nutrition security for all will depend on increasing food production. This, in turn, means ensuring the sustainable use of our most critical finite source - water".

The world population is predicted to grow 8.3 billion in 2030 and to 9.1 billion in 2050. By 2030, food demand is predicted to increase by 50% (70% by 2050). It means 50% to 70% increase in water use.

As noted by Rahman (2017) we have done very well in many areas of water resource management, but our failures in certain areas have caused misery to millions of people such as increased salinity due to over irrigation, failure of dams causing deaths and destruction, and water contamination by micro-plastics.

4. WATER AND SUSTAINABILITY EDUCATION: EXAMPLES IN LITERATURE

Middlestadt et al (2001) presented a case study on water conservation education in Jordanian schools. This study measured the effectiveness of advising on water conservation within homes and also the impact of educating students and families to promote water conservation behaviours. The participants were selected at random where comparisons were made among 671 high school students in central Jordan, where 424 of the students were ‘experimental’ and 247 students were ‘control’. The investigated groups involved of students whom existed in classes where the teachers implemented an interactive curriculum and promoted water conservation practice. The control group however, did not participate in classes with curriculum implementation but were exposed to lectures on biodiversity issues. The results show that the students involved in the interactive curriculum activities had a higher level of knowledge and understanding about water conservation and demonstrated more frequent water conservation practices compared to students within the control group.

Blanton et al (2007) presented a case study on the role of school children in the promotion of point-of-use water treatment and handwashing in schools and households in Western Kenya. This study examined the effect of training teachers to promote water treatment and in addition, drinking water and handwashing stations were installed in 17 rural schools. They also aided in treating the water by providing schools with flocculent-disinfectant powder and hypochlorite solution. Blanton et al (2007) conducted a baseline water handling survey of students’ parents from 17 schools and tested stored water for chlorine. They then conducted follow-up surveys and chlorine testing at 3 and 13 months. It was found that parental awareness of the flocculent-disinfectant increased, awareness of hypochlorite remained high and also household use of flocculent-disinfectant and hypochlorite increased and were maintained after 13 months. Furthermore, the absentee rates of students decreased by 26% after implementation and also a significant increase in household water treatment procedures were observed.

Laurence et al (2007) presented a case study on the effect of a health promoting schools’ approach to increasing consumption of fruit and water in Australia. The ‘Fresh Kids’ program formulated an agenda where they concentrated on promoting behaviours related to healthy eating and reducing the risk factors associated with childhood obesity. The objective of the program was to increase fruit and water consumption among school children over a period of 2 years. The study involved four primary schools in the inner west of Melbourne, Australia. Baseline data was collected to assess the frequency of children with fresh fruit, water and sweet drinks, which were either brought from home or bought from the canteen. The lunchbox inspection was repeated continuously for up to 2 years following program implementation to assess the sustainability of dietary changes. Within all participating schools, increases between 25% and 50% were observed in children bringing fresh fruits. Furthermore, all schools recorded increases between 15% and 60% of children bringing filled water bottles to school and a reduction between 8% and 38% of children bringing sweet drinks. These important changes were present and sustained for up to 2 years following the program's implementation.

Higgs and McMillan (2006) presented a case study on teaching through modelling and the experiences in sustainability education. The authors examined how four innovative secondary schools' model sustainable practices within their students. The authors frequently visited four schools conducting interviews. Furthermore, they also observed daily interactions and reviewed school documents. They found that modelling is an effective approach to sustainability education, whereby they observed the promotion of both learning about sustainability and also adoption of sustainable behaviours in these four schools. The four primary methods in which the schools model sustainability are individual role models, school facilities and operations, school governance, and school culture. Other schools interested in promoting sustainability education will likely find these approaches to modelling effective.

The above studies show that water education can be enhanced in schools by adopting specially designed projects. Water Education and Research Committee in Australian Water Association has a number of programs to promote water education in schools and universities in Australia. Water education depends on the status of science education as explained in Rahman et al. (2018).

5. WATER EDUCATION IN AUSTRALIAN SCHOOLS

5.1 Curriculum overview

Australian high school education is based on the Australian Curriculum, Assessment and Reporting Authority. This report will focus on the NSW Education Standards (NESA) syllabus, providing an overview of water content delivered in NSW schools across the major Key Learning Areas including Geography, History, Science and 'Personal Development, Health and Physical Education' (PDHPE).

Geography has the largest focus on water education whereby an entire Stage 4 (years 7-8) module is dedicated to water. The module is called "Water in the World" and the content is divided into the topics of: water resources, water cycle, Australia's water resources, water scarcity and water management and the value of water. A few examples of specific syllabus points surrounding the topic of water from the Geography syllabus are outlined below:

- **"Space:** the significance of location and spatial distribution, and ways people organise and manage spaces that we live in e.g., water resources.
- **Interconnection:** no object of geographical study can be viewed in isolation, e.g. how people are affected by the environment with regard to...use of water on its quality and availability as a resource.
- **Sustainability:** the capacity of the environment to continue to support our lives and the lives of other living creatures into the future, e.g. pressures on the Earth's water resources...the need to manage environments for a long-term future; sustainable management approaches.
- Students examine water as a resource and the factors influencing water flows and availability of water resources in different places.
- They investigate the nature of water scarcity and assess ways of overcoming it.

- Students discuss variations in people's perceptions about the value of water and the need for sustainable water management.
- Students also investigate processes that continue to shape the environment including an atmospheric or hydrologic hazard such as flood.

Science teaches aspects surrounding water beginning from Stage 1 (K-2) until Stage 6 (years 11-12). Table 1 describes syllabus points students are required to learn regarding water. In addition to direct content related to water, Science in NSW also explores the chemical composition of water, beginning from Stage 4. As of 2019, Stage 6 (year 11-12) Biology is no longer required to teach specific diseases, however teachers often include diseases spread through water.

History has elective topics in Stage 3 (5-6) and 4 (7-8) which explore the social aspects of water. Topics from the syllabus include:

- Stage 3: The diversity and longevity of Australia's first peoples and the ways Aboriginal and/or Torres Strait Islander peoples are connected to Country and Place (land, sea, waterways and skies) and the implications for their daily lives.
- Stage 4: The cultural achievements of the Khmer civilisation, including its system of water management and the building of the temples of Angkor.
- Stage 4: Theories of the decline of Angkor, such as the overuse of water resources.

PDHPE focuses on physical water safety with students in the form of swimming beginning from Stage 1 to 5. Various topics of water safety are also expanded on such as:

- Stage 3: Describe the place of water-based recreational activities in Australian society and how communities come together to enjoy water-based activities.
- Stage 5: Plan and practise responses to emergencies by explaining priority actions and where they may be required to administer first aid, e.g. in and around water.

5.2 A case study

An informal study was conducted where randomly selected school students were asked basic questions to test their knowledge on water. Ten questions were asked to three age groups, where different group were asked different sets of questions. The questions can be seen in Tables 2, 3 and 4. The three age groups were 'KG-6', 'grade 7-10' and 'grade 11-12'. The answers provided by the students were marked out of 10, assessed by the last author, who is a water expert.

From our gathered results, we can see that the average marks for 'KG-6', 'grade 7-10' and 'grade 11-12' were 65.71%, 43.33% and 47.5%, respectively (seen in Table 5, Table 6 and Table 7). The slight increase of 'KG-6' results compared to the other age groups may indicate that the relative knowledge for their age group is generally satisfactory. A further analysis of the results from Table 5 (KG-6) show low scores for question 3, question 8 and question 9. These questions address the issue "which water is safe to drink". The low average score of these questions indicate that individuals within that age group are unaware of the harmful danger of contaminated water.

In Table 6 (grade 7-10), it can be observed that the average score is 0 for question 3. This exemplifies that individuals within the age group of 'grade 7-10' do not know which of their home appliances use the most water. This inadequacy of knowledge can also be seen in the age group 'grade 11-12' where the average of question 9 is '2.5' (seen from Table 7). From this it can be argued that individuals within this age group have little knowledge about the Queensland flood, which was one of the worst floods in Australian in recent years, causing over a $30 billion loss to the Australian economy.

These results indicate that overall the knowledge of water is not very high within the investigated school students. However, a formal survey is needed involving more schools and a greater number of students to confirm this initial finding.

Table 1: Syllabus explaining students' learning requirements regarding water (NSW)

Stage (years)	**Syllabus Points**
Stage 1 (K-2)	• Describe what plants and animals, including humans, need to stay alive and healthy, e.g. food, water and air (page 37) • Identify that some common resources are obtained from the Earth, including soil, minerals and water (page 44) • Share their observations and ideas about the ways that water is used by people in their daily lives (page 44) • Identify some actions which could be taken to care for and use water sustainably, e.g. turning off dripping taps and/or taking shorter showers (page 44)
Stage 2 (3-4)	• Describe some changes in the landscape that have occurred over time as a result of natural processes, e.g. erosion by wind and water (page 55)
Stage 3 (5-6)	• Identify some physical conditions of a local environment, e.g. temperature, slope, wind speed, amount of light and water (page 69)
Stage 4 (7-8)	• (a) Identify that water is an important resource that cycles through the environment (b) Explain the water cycle in terms of the physical processes involved (c) Demonstrate how scientific knowledge of the water cycle has influenced the development of household, industrial and agricultural water management practices (page 109) • Explain that the systems in multicellular organisms work together to provide cell requirements, including ...water...and to remove cell wastes (page 112) • Describe the importance of water as a solvent in daily life, industries and the environment (page 115)
Stage 5 (9-10)	None
Stage 6 (11-12)	**Biology**: • Trace the digestion of foods in a mammalian digestive system, including...water (page 39) **Chemistry**: • Demonstrate, explain and predict the relationships in the observable trends in the physical and chemical properties of elements in periods and groups in the periodic table, including but not limited to...reactivity with water (page 37) • Describe and analyse the processes involved in the dissolution of ionic compounds in water (page 51) • What is the role of water in solutions of acids and bases? (page 53)

Table 2: Questions for KG-6 students

Questions
1. Where can you find water?
2. Can you drink any water?
3. How do you know when water is not drinkable?
4. What is the main source of water?
5. Can you swim in all types of water?
6. How much time do you spend having a shower?
7. Is water free?
8. Can you drink water in poor countries?
9. What diseases can be caused by dirty water?
10. Why do you need to wash your hands before eating?

Table 3: Questions for 7-10 students

Questions
1. What molecules are water composed of?
2. Have you heard about the water cycle?
3. Which s activity consumes the highest amount of water?
4. What are the dangers of flooding?
5. Where does water from our taps come from?
6. How can we minimise wasting water?
7. How many people in the world have access to less than 5L of water a day?
8. Name 3 diseases caused/transmitted by water?
9. If there were no water taps, where could you get water from?
10. What is the price of tap water in Sydney?

Table 4: Questions for 11-12 students

Questions
1. What components can water be broken into and how?
2. Do any planets other than Earth have water?
3. How would you access water in the Australian desert?
4. How many people in the world have access to less than 5L of water a day?
5. How much does the tap water in Sydney cost?
6. Where does toilet water go?
7. How can you save water?
8. What is a flood? How many people die during floods each year?
9. How much damage was caused by the Queensland flood in 2010?
10. What is meant by "drought?" How do droughts affect the Australian community?

Table 5: Results of responses from KG-6 students

Question	P1	P2	P3	P4	P5	P6	P7	AVERAGE
Q1	10	10	10	0	5	10	10	7.86
Q2	10	10	10	10	10	10	10	10
Q3	0	5	5	5	0	5	0	2.86
Q4	0	10	10	5	5	10	0	5.71
Q5	10	5	0	10	0	10	10	6.43
Q6	10	10	10	10	10	10	10	10
Q7	0	0	10	10	5	10	10	6.43
Q8	10	0	0	10	0	5	0	3.57
Q9	5	5	5	0	5	5	5	4.29
Q10	10	5	10	10	10	10	5	8.57
TOTAL	65	60	70	70	50	85	60	65.71

Table 6: Results of responses 7-10 students

Question	P1	P2	P3	AVERAGE
Q1	5	5	10	6.67
Q2	10	10	10	10
Q3	0	0	0	0
Q4	5	5	5	5
Q5	0	5	5	3.33
Q6	5	5	5	5
Q7	5	10	0	5
Q8	5	0	5	3.33
Q9	10	0	5	5
Q10	0	0	0	0
TOTAL	45	40	45	43.33

Table 7: Results of responses 11-12 students

Question	P1	P2	P3	P4	AVERAGE
Q1	10	10	5	10	8.75
Q2	10	0	0	10	5
Q3	0	5	5	5	3.75
Q4	0	0	0	0	0
Q5	0	0	0	0	0
Q6	10	10	10	0	7.5
Q7	5	0	5	5	3.75
Q8	5	0	10	10	6.25
Q9	0	0	5	5	2.5
Q10	10	10	10	10	10
TOTAL	50	35	50	55	47.5

6. CONCLUSION

This paper presents an overview of water education in Australia. It has been found that the NSW school curriculum contains a thorough water conservation component; however, mathematical aspects of water science are not covered well. It is important that water concepts are taught at schools at a higher level to make water-educated citizens who value this important resource and to also develop a group of students who will pursue water education at a tertiary level to become water experts. This will help us to tackle water challenges in a warmer climate more effectively where water demand will be higher but water availability will reduce and water disasters will increase in frequency and intensity. Water education will assist to achieve sustainable development in Australia.

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Writing of a Higher Degree Research Thesis: Perspectives of a Student, Supervisor and Thesis Editor

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Abstract

Academic writing skills are essential for higher degree research (HDR) students. At the beginning of the candidature, a HDR student is required to write a literature review critically analysing the state-of-the art knowledge on the given research topic, identifying limitations of the current knowledge and areas of further research. The literature review culminates with the HDR student clearly defining their topic. They are then required to prepare a research proposal written in a professional manner and presented to a confirmation panel who must be able to understand and appreciate the research area and innovation of the proposal. In the second year of candidature, a HDR student is often expected to write a refereed conference paper and sometimes a refereed journal article. In the final year, a thesis needs to be written that should reflect a mature understanding and significant innovation and contribution to knowledge. All this requires a high level of literacy both in analysing others research and in publishing their own. This paper presents the experience of a thesis editor, a HDR student and an award winning HDR supervisor on the aspects of writing issues. It has been found that a student with good writing skills publishes more papers than a student with poor writing skills. This also presents a strategy for how a HDR student can enhance his/her writing skills to complete his/her HDR degree successfully.

Keywords: HDR student, research writing, academic writing, PG study, thesis

1. INTRODUCTION

Writing of a doctoral thesis is perhaps the biggest writing exercise of a person's life that is intellectually demanding and often a matter of stress and anxiety. Students coming from non-English speaking background often find doctoral thesis writing a challenging task although many of them possess an excellent analytical skills to complete the doctoral analysis/experiments. The new generation students often put less important in writing which often creates issues in their academic writing of thesis at undergraduate and postgraduate (PG) levels.

Kroll (2018) noted that a student and his/her supervisor develop a complex relationship during the candidature period that revolves around multiple types of text. The feedback by the supervisor is important in this process as the student reads the minds of his/her supervisor from the feedback/comments. Jeyaraj (2018) conducted a semi-structured interviews in Malaysia with six PG research students from non-native English-speaking backgrounds and noted that the academic language demands in thesis writing were challenging, which affected the thesis writing. There was an absence of clear direction in writing.

Peng (2018) presented how Chinese students faced difficulties in writing PG research theses. The most difficulty was around "narrative literature review" and "lack of conceptual framework". They noted that many graduate students depend heavily on their supervisors in writing a thesis irrespective of their performance on graduate entrance examination.

Aitchison and Mowbray (2015) stated that the growing diversity of the doctoral research students is placing significant pressure on university resources to help the thesis writing by the students. It is expected that doctoral students will produce high quality publications or thesis even though the student cohort may have little writing experience although they may have excellent mathematical or modelling ability. Aitchison and Mowbray (2015) reported 158 online writing support provider sites and data from follow-up interviews and surveys for helping doctoral thesis writing. Many of these services are "questionable", although some are "competent". They found that there is "considerable fuzziness in regard to the ethical and educational legitimacy of accessing external help for writing the doctoral thesis."

There is a lack of research on doctoral thesis writing and often there are so many issues associated with doctoral thesis writing that no generic solution/guideline can be made. This paper present a case study where a PG student (English as the first language and engineering background) presents his experience of writing, a supervisor (English as his second language and engineering academic) presents few important tips in writing a doctoral thesis and a thesis editor (English as his first language and completed English degree from an Australian university) provides his perceptions.

2. SUPERVISOR'S PERSPECTIVES

The third author of the paper has supervised over 30 HDR students and has edited/corrected over 100 theses. He has also examined 21 PhD theses. His ten tips in thesis writing are summarised in Table 1. It should be noted that this can be taken as a guide only, different supervisors have different styles of guidance in writing a thesis. The supervisor's major role is to motivate and encourage students to start writing at the earlier part of the candidature. A conference paper writing in the first six months help a student to learn academic/research writing. Joining a writing circle is often useful. Guidance from senior PhD students or recently completed PhD graduates is often helpful.

The third author guided over 30 HDR students to write over 150 refereed articles which have helped his HDR students to learn academic writing. They all produced a good quality thesis at the end, but not without notable hardship/difficulties.

Table 1: Ten tips in PhD thesis writing by the third author

Tip	Description	Comments
1	Take PhD thesis writing as a challenging task	If one takes it lightly, a good thesis cannot be made in a timely manner
2	Have a good thesis outline with all the major headings, sub-headings, all figures, tables and appendices titles	This should be agreed by all the supervisory panels
3	In the first draft preparation, not to worry too much on English writing structure, but focus should be on the information.	First draft can be made in one's own language if English is not strong for the candidate.
4	Select a place and environment where one can make the best writing, e.g. quiet environment, good temperature and no interference.	Poor environment restricts brain's logic and best outcomes are not achieved.
5	Do not keep mobile, email all the time, use it after every two hours block.	Break in between writing blocks help to achieve better standard.
6	Do not leave the writing for the last moment, start writing from month 3 of candidature, the literature	Progressive writing to be submitted to supervisors and comments to be given

	review report should be drafted by the 9 months of candidature.	to candidates quickly.
7	Formatting to be in the front desk: font type and size, major, minor and sub headings, line spacing, all other styles.	Consistency is a major issue in many theses.
8	References should be completed at the time it is inserted in the text, not to be left for the last moment.	References is an area where many thesis lack in perfection.
9	Test whether one likes reading one's own thesis, if one does not like, how the examiners will like it.	Enjoy writing and reading of the thesis. Completeness and connectivity are important.
10	Remember, one is writing the thesis for the examiners.	Examiners are critical persons with high level knowledge, one cannot fool the examiners.

3. EDITOR'S EXPERIENCE

The first author of the paper has edited over 10 theses and refereed papers from the field of engineering. He has background in English literature. The most common mistakes he found in editing these theses are listed below:

Mistake 1: Use of articles, "the" and "a" is a major issue for non-English speaking thesis writer.

Mistake 2: Inconsistency of styles across chapters.

Mistake 3: Sentence structure is poor and meaning is not clear.

Mistake 4: Repetition of facts when not needed.

Mistake 5: Abbreviation is not done at the right place, i.e. in the first instance.

Mistake 6: References is poor, inconsistency in the styles.

Mistake 7: Typing of equations, symbols, vector and matrices are not as per tradition.

Mistake 8: Boring writing i.e., little efforts by the writer to make the thesis an enjoyable reading.

Mistake 9: Lack of connectivity and cross referencing.

Mistake 10: Spelling error and poor grammar.

4. PG STUDENT'S TIPS

If one comes topic area is not a literature based subject such as English, history, law, etc. or if English is a second language, then one will probably need to make a particular effort to improve their writing skills. Scientists and engineers are known to have bad communication skills (Rahman et al. 2016). The first tip then is to take an interest in reading. Academic writing in many ways has its own particular language and etiquette but this doesn't mean that one must restrict their reading to academic literature. Reading books is a dying pastime that brings great benefit.

The second tip is to take an interest in writing. Not all engineers have bad writing skills and there have been a number of engineers in history and contemporary that have shown excellent communication skills (Rahman et al. 2018). Write in as many ways as you can. If you have friends or family which have good writing skills ask them to help proof read your work, if they are not an expert this may be even better as one often needs to be able to write and explain things in a way that is understandable by lay people.

The third tip is to take advantage of the nature of a PhD. Right from the outset of candidature the PhD student will be engaged in reading many articles, particularly in the literature review stage. If one makes a little bit extra effort this is a great time to improve their literature skills. Attend writing courses provided by the higher degree research (HDR) unit, make friends with a librarian, become a member of Oxford dictionaries online. Take a little time to read about reading!

The fourth tip is to present one's work as early as possible and as much as possible. This has a number of advantages. Presenting one's work forces one to consolidate one's ideas in a presentable manner. It also puts it out into the scientific community for constructive criticism and valuable feedback that one can build upon, this should not be left to the final presentation.

The Fifth tip is to publish one's work as early as possible and as much as possible. This has the same advantages as presenting ones work in conferences but with the added advantage of focusing more particularly on literature skills.

The sixth tip is to never give a first draft to your supervisor. This is for a number of reasons, firstly it will be harder for them to read, secondly they are likely to focus and comment on the minor mistakes that one can correct one's self rather than the more important issues that need their attention. In so doing their time is wasted and one has missed out on valuable comments on the more important issues in the Thesis

The Seventh tip is to submit one's work in stages and in a timely manner. A thesis is large documents so don't expect to give it all to the supervisor two weeks before it is due and get a thorough analysis and response the week after. Rather it should be written throughout the candidature and presented to the supervisor in stages. Publishing journal articles can help in this process by giving one targets and deadlines.

5. CONCLUSION

Academic writing is a challenging task. Doctoral thesis writing is one of the most intensive writing exercises in one's career. The major difficulty in doctoral thesis writing is found to be with the students coming from non-English speaking thesis background. Many students do not take thesis writing a serious task at the beginning of the candidature, which put them in great pressure at the end. Progressive writing is the best possible option where writing of a refereed paper in the first year of the candidature is found to be useful. The supervisor's encouragement, critical commenting and timely feedbacks are few of the important elements that helps a student to write a good thesis.

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The Facilitation of Flipped Learning within the Classroom Environment

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Abstract

An essential element towards the delivery of a successful lecture and enhanced student learning is student engagement. Prevailing pedagogy literature suggests a number of blended learning techniques can be adopted by the practitioner to gain student interaction and develop deeper levels of student learning. More specifically, the application of flipped learning within the classroom environment is recommended. Also known as a flipped classroom, an inverted classroom, or similar to the principles of directed independent learning, this teaching technique shifts the learning environment from teacher-centric to student-centric, with the aim to encourage independent self-learning and enhance student skills.

This paper presents research that has explored the adoption of the flipped learning technique within classrooms of Built Environment (BE) students. The teaching technique was applied to three different classroom environments, studying the use and facilitation of flipped learning to diverse class sizes and levels of study. Findings highlight the benefits for the adoption of flipped learning, which are primarily associated with enhanced student understanding of the subject. Results further indicate, due to the value of student engagement to the teaching technique, the practitioner may need to consider the facilitation of flipped learning within the classroom environment.

Keywords: blended learning, flipped learning, the Built Environment, teacher-centric learning, student-centric learning.

INTRODUCTION

An essential element towards the provision of a successful lecture is to engage students, engage their brains to get them thinking and asking questions (Race, 2009). More specific to studies within the engineering education discipline, students are encouraged to be less passive to the information provided and more involved in learning activities (Dickens and Arlett, 2009). Support for a more active student is also present in construction education literature, which evidences greater levels of learning through student interaction (Abdelhamid, 2003). This generation of student involvement within the classroom environment is more commonly known as active learning.

There are a number of diverse methods advised to generate interaction within the classroom. Blended learning techniques adopted by the practitioner, for example, in addition to the integration of technology and changes to the classroom structure, are available to promote student engagement. A teaching method advocated within the construction discipline that allows students to think independently prior to the lecture, is the application of flipped learning (Roehl et al. 2013), also known as a flipped classroom, flipped education or directed independent learning (DIL) (Thomas et al. 2015).

The prescribed techniques for flipped learning appear an uncomplicated application to advance student engagement and greater levels of learning within the classroom. The current literature supports the benefits of self-learning and independent thinking prior to the lecture (Ahmed, 2016; Thomas et al., 2015), however, there is a lack of instruction in terms of how to undertake the process. There is also little insight from empirical evidence where flipped learning has been applied, along with possible challenges. To further support research surrounding the implementation of a flipped classroom, as a practitioner the difficulty of student engagement for deeper learning within teaching are prevalent, where various levels of communication have been experienced during student contact time. Interaction levels can vary due to student interest in the module content, knowledge of the subject or the structure of the lesson. As well as difficulty in encouraging teacher-student interaction (Vaughan, 2014), it can be a challenge to encourage peer interaction.

Previous experience and literature highlight the need to investigate the application of flipped learning in different learning environments, as well as understanding the facilitation of this learning technique. The aim of this research was to investigate the adoption and facilitation of flipped learning within the classroom environment in order to enhance learning for students of the Built Environment (BE), in addition to further identify the challenges of its application. The structure of the paper is as follows. First, pedagogy literature on the subject of blended and flipped learning techniques are reviewed. Second, the research design and methods adopted for the investigation are explained. Third, results from the investigation are presented and discussed. Finally, conclusions are drawn for contribution to theory, as well as the potential areas for further study.

LITERATURE REVIEW

What is flipped learning?

Flipped learning is referred to as a teaching technique that can be applied to the classroom environment to enhance student learning, as well as support student engagement. In simple terms, the flipped learning model shifts the learning environment from teacher-centric to student-centric in order to gain greater student engagement and learning (Ahmed, 2016). There are various other concepts used interchangeably for flipped learning within the literature, such as the adoption of a flipped or inverted classroom (Vaughan, 2014) and flipped education. Additionally, with similar principles to flipped learning, directed independent learning (DIL) or independent study, appears to encourage autonomous learners and a deeper level of interaction. DIL emphasises the importance of student effort and if facilitated, the adoption of this method can lead to a greater number of classroom discussions and deeper learning for students. To encompass the various meanings of this teaching technique, a broad definition states flipped learning consists of *"a shared idea of making a student ready for a session...using one of a range of diverse instruments to permit the learners more free time in class to develop their skills and show proficiency of skills and knowledge"* (Ahmed, 2016:420). It must also be noted that there are flipped learning definitions that refer specifically to the use of technology for the teaching technique (Jensen et al., 2015). It is not clear whether this may be the use of a learning platform, such as Blackboard, or various other technology applications within the classroom environment.

Student-centric learning for a deeper student understanding

To understand the concept of flipped learning and its application, it is important to understand the 'four pillars' of the teaching technique, which consist of a flexible environment, learning culture, intentional content and professional educators. In order to gain an effective working environment through the integration of the flipped learning technique, there is a need to consider each individual pillar (Ahmed, 2016). It is also important to highlight that there are many different models for flipped learning. A common instruction, however, which can enhance the value of flipped learning, is the focus on the learning rather than the teaching. Within this context, the flipped learning technique aims to allow students the space to think independently and adopt self-learning prior to the lecture, which can result in a deeper understanding of the subject area (Ahmed, 2016). The flipped classroom can also allow more free time within the teaching time allocated, where the practitioner can concentrate on student difficulties (Roehl et al., 2013) or the generation of collaborative working. In contrast to studies that emphasise the need for flipped learning to generate a deeper student learning within the classroom, there is also literature that state other blended learning techniques are just as effective (Jensen et al., 2015).

Flipped learning as a solution to student engagement

Flipped learning has been applied within previous studies to highlight the benefits to the student experience and a driver of student learning (Ho, 2017; Roach, 2014), as well as an aid to teacher-student engagement (Vaughan, 2014). As learners are provided content information and key texts on the subject, or foundation knowledge on the topic that will be essential to the understanding of the lecture material, there is a focus for classroom discussion. The opportunity for a classroom discussion provides a driver for student engagement within the learning environment. In greater support of flipped learning, the adoption of the technique has not only been successful in engaging students and enhancing classroom discussions, but also encourages the development of essential attributes for students. Previous studies have shown the enhancement of student skills, such as creativity and independent thinking, which are key employability skills (Kneale, 2009). The application of flipped learning has further demonstrated value for students in regards to a greater interest in the subject and enhanced confidence (Ho, 2017). Finally, there is evidence that flipped learning can be beneficial for the practitioner, such as the enhancement of skill development through the preparation and the implementation of the teaching method, e.g. creation of teaching material, content and use of technology (Vaughan, 2014).

Current literature on the subject of flipped learning advocates the blended learning technique towards deeper learning for the student within the BE and other disciplines. Prevailing studies further highlight the value of flipped learning for greater student engagement within the classroom environment, in addition to the development and enhancement of essential student skills and potentially, greater interest in the subject area. Prevailing pedagogy literature, however, appears vague in terms of how the technique is implemented in practice, along with any challenges of the teaching method. As Roach (2014) states, for example, the integration of flipped learning is valuable within the teaching environment, but the technique does require facilitation by other methods, possibly blended learning techniques. There is little insight, however, of what the other teaching practices consist of. There is also the concern for the practitioner of time required to develop the classroom material, in addition to the content for the flipped learning technique to be put into practice (Vaughan, 2014). Moreover, there is little empirical evidence for the presence of student engagement through the implementation of flipped learning, in addition to studies that demonstrate greater student interaction being a result of flipped learning. The prevailing literature supports the need to gain a further understanding for the integration of the flipped learning technique within the classroom environment, along with studying the benefits and any challenges experienced by the practitioner and the BE students.

RESEARCH DESIGN AND METHODS

The research applied the flipped learning technique to three different class sizes, in addition to a variety of both undergraduate (UG) and postgraduate (PG) learning environments. The teaching environments were chosen to investigate flipped learning for different cohort sizes, diverse subjects (e.g. postgraduate programmes within the BE department) and a range of student levels (e.g. UG and PG students) within higher education. The three classes were given materials to read and examine prior to the lecture, all uploaded on the learning platform known as Blackboard. A class of 30-35 UG students were given an article on the subject material, connected to a forthcoming assignment; a class of 19 PG students were provided with an image and asked to prepare answers following the analysis of the image; a class of 8 PG students were given a literature review to read and asked to provide comments on how the piece of work could be improved. During the three classes, the flipped learning material provided was encouraged to be discussed through a form of interaction between the practitioner and the students. During times of no or little teacher-student / peer discussion, previously prepared blended learning techniques were integrated within the classroom environment, e.g. the use of technology applications, changes to the classroom structure and further blended learning techniques. Following the lectures, notes were taken on the levels of practitioner-student interaction, peer engagement and discussions within the classroom.

RESULTS AND DISCUSSION

The application of flipped learning

The application of flipped learning to each learning environment required preparation beforehand, such as the creation of appropriate documentation and content for the upload onto the learning platform, known as Blackboard. The flipped learning technique evidenced an uncomplicated practice to design and adopt for the practitioner and, depending on the class size, preparation was not time demanding. There was also evidence of skill development for the practitioner. A greater understanding of the learning platform, for instance, along with consideration of the most appropriate method to display the subject content.

The response to flipped learning

The adoption of flipped learning in all three cases evidenced variations in student engagement and teacher-student / peer interaction. First, the PG (19 student class) flipped learning activity generated a high level of classroom discussion and questions from students surrounding the content of the work. The flipped classroom activity (an image and questions) also encouraged creative thinking by a number of PG students, where student debates and subject feedback were generated within the lecture. Second, the PG (8 student class) evidenced greater levels of interaction than previous years (2016/2017), where no documents were provided prior to the lecture. It must be noted that the discussions within this class were directed by the structure of the classroom, e.g. the seating was arranged in a circle with students facing inward. There was also evidence of peer interaction within both PG classes. In contrast, the UG (30-35 student class) flipped learning case did not engage students to the level of the previous PG classes. Students were engaged with the article (evidence of it being looked at), but there was little evidence of motivation to discuss the work. Further blended learning techniques, such as the use of technology applications (e.g. Mentimeter) and classroom structure, were incorporated to encourage teacher-student engagement, in addition to peer interaction.

Flipped learning in practice

The investigation demonstrated the use of flipped learning was of benefit to the classroom environment due to evidence of enhanced student understanding associated with the subject. The research further suggests the deeper levels of learning appeared to be a result of greater student engagement and interaction within the classroom environment. In relation to the flipped learning technique, what appears to be key to its success within the classroom environment is primarily the result of student-teacher engagement or peer interaction associated with the learning activity. Within the investigation, it was this student interaction that generated an interest, a discussion and enhanced the levels of student learning. Similar to previous studies (Ho, 2017), evidence of enhanced student confidence was present during the investigation. Furthermore, to resonate with existing literature (Ahmed, 2016), the benefits of free time to discuss the key points of the flipped learning content, in addition to essential student concerns on the topic, were clear during the study.

The facilitation of flipped learning

The adoption of the flipped learning technique appeared to be of benefit in terms of student learning and understanding of the subject area. The findings further highlighted, however, the need to incorporate other blended learning techniques, which can encourage student engagement within the flipped learning activity. It appears that student engagement is essential to the practitioner to understand the presence of student understanding, along with promote student interaction for deeper levels of learning. The large UG class, for example, required additional blended learning techniques to be incorporated to create student interaction. Similar is the message by Roach (2014), where blended learning techniques can complement the flipped learning method. To further extend this literature, the additional learning techniques not only enhanced the student learning, but on occasions, essential to the classroom environment in order to develop the value of the flipped learning.

The results also indicated the choice of the flipped learning material may have an effect on the value of the technique. Through a comparison for the provision of solely a reading and a reading with questions to guide the student, highlighted the support and possible ease for student engagement with the article. The two PG classes, for instance, both with varying levels of guidance for the flipped learning materials, emphasise the benefit for the adoption of the appropriate flipped learning material. The questions within the flipped learning material (the larger PG class) allowed the students to engage with and prepare for the class prior to the lectures. Similarly, the notes on the flipped learning content (the smaller PG class) encouraged a discussion within the classroom and promoted independent thinking before and during the class. In further support for the consideration of the flipped learning material, the additional blended learning technique in the larger UG class provided this level of guidance due to questions asked in regards to the flipped learning material provided (e.g. a line up where students were required to state the usefulness of the article). To further extend the ideas within the literature (Vaughan, 2014), this research highlights, in addition to the allowance of time for the practitioner, the choice of learning activity and flipped learning material is also important. Finally, in support and to advance current studies for the integration of flipped learning (Jensen et al., 2015), a significant role is required by the practitioner (inside and outside of the classroom). The need for control may be in reference to the choice of the flipped learning material provided, or the addition of appropriate blended learning techniques or technology to facilitate the teaching technique.

CONCLUSIONS AND RECOMMENDATIONS

The investigation explored the adoption of flipped learning for the BE students and its facilitation within the classroom environment. The integration of the flipped learning method was of value to the learning environment within all three classrooms. The results evidenced enhanced levels of student understanding on the subject through classroom discussions and greater levels of student interaction. There were instances, however, where the flipped learning technique was of greater benefit within the classroom and to student learning than others. Findings suggest the class size and the flipped learning content / activity provided for the teaching method requires consideration by the practitioner. The research further emphasised the importance of classroom interaction in order for the flipped learning technique to be of value. In support of current literature, the research recommends the facilitation of the flipped learning technique by other blended learning methods, which can provide student engagement and aid classroom discussions surrounding the learning activity/ content.

In terms of future areas of research, it would be advantageous to explore the use of flipped learning within smaller size UG classes and variations of flipped learning activities, such as guided reading, questions surrounding the activity and the use of different technology applications. Further study surrounding the adoption of blended learning techniques that can enhance classroom discussions, along with investigating the effective methods to facilitate flipped learning, would be of value to the adoption of the technique within higher education.

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Hydrology Teaching: An Example of Student Learning Using Flood Frequency Analysis

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Abstract

Hydrology is one of the common subjects in engineering study. Hydrology courses often contain flood risk analysis as flood is one of the most catastrophic natural disasters globally. For example, during 2010-11, the flood damage in Australia exceeded $30 billion and costed over 30 lives. To minimise the flood damage the best approach is to predict the severity of the flood by analysing recorded flood data sets available at the location of interest. This paper presents the learning experiences of students based on a case study on flooding problem in South Australia. It examines the frequency of floods in South Australia by using two commonly used probability distributions, namely Generalized Extreme Value (GEV) distribution and Gamma distribution. It has been found that although South Australia is a drier state in Australia, it suffers from severe flooding occasionally. Furthermore, this paper shows the difficulties in flood frequency analysis in relation to learning and applying it as methods produce significantly different results at higher return periods, which are relevant in the design of large infrastructure projects. On this regard, it compares the hydrology courses of three universities: University of Technology Sydney, Bangladesh University of Engineering & Technology and Western Sydney University.

Keywords: Hydrology, floods, South Australia, GEV, Gamma, blended learning

1. Introduction

Water is an essential element for our existence. It is fundamental to our environment and ecosystem.It is the source of life for all the living things. Singh (2008) truly stated that "millions of people on this earth live without love and affection, but no one can survive without water even for a few days". It is essential for us to live and grow; however, it can also be a cause for loss of lives and properties when it is not controlled properly such as during catastrophic floods (Rahman, 2017).

The need of water knows no bounds in our lives. From the very beginning of our day to the very end of it, we desperately need water. We use water for various purposes. The use of water can be categorized into three sectors such as personal, industrial and agriculture. Water is used for washing, cleaning, soaking and cleansing our daily household items. As for industrial use, everyday billions of gallons of water are used throughout the whole world in major industries. From cooling a high-powered engine to cleaning and cutting small piece of machinery, we use water. Agriculture of any kind vastly depends on water as plants need it to survive and flourish.

Proper distribution of water is extremely crucial for our existence. If the quantity of water is insufficient than required in a specific region, then it causes droughts. If the quantity is more than what is needed, then it turns into a flood causing damages to life and property. Quality of the available water is also very important. Water needs to be clean for us to drink it. There are plenty of water in the sea which cannot serve the purpose of drinking. For agriculture, water available at that location need to have a certain pH level and free from chemical contamination to be suitable for plants and harvesting. Some areas of a country may have plenty of water whereas other areas might be in need, so the spatial distribution is an important factor when it comes to water and this needs to build water pipelines to carry water from one to another part. Some of these pipelines extend hundreds of kilometers.

Water can also be disastrous if not contained with precaution. Natural disasters such as Typhoon and floods can strike a huge blow to a country's economy as well as to its people. Climate change in recent years have caused water related disasters like floods to increase significantly (Ishak *et al*., 2013).

Hydrology is a subject that focuses on the movement and occurrence of water and is a compulsory subject in many engineering courses (Rahman et al., 2018). This paper highlights the significance of hydrology from a student's perspective. It also presents results of a case study where the first author learns flood frequency analysis (a topic in hydrology) from the third author, who is a senior academic in Western Sydney University.

2. Different teaching methods

According to Rugarcia et al. (2000), knowledge is the database of professional engineers and skills are the tools used to manipulate the knowledge in order to meet a goal dictated or strongly influenced by the attitudes. There are different approaches when it comes to teaching methods such as active learning, passive learning, blended learning and online learning (Rahman and Ilic, 2018). In passive learning, students learn directly from the teacher via face to face interactions. Students obtain their knowledge from reading the book or from attending lectures. It is a one-way traffic of education and was very popular in the past. Active learning is a process where students get involved in various learning activities and learns throughout the way of studentship. They are engaged in numerous activities such as case studies, group projects and presentations. The teachers get to learn from their students via this process as well. Another form of learning technique is blended learning, which combines online and face-to-face teaching methods. This is a more advanced form of active learning as students get to learn via different resources available online and in person. Online learning does not require students to attend classes or tutorials as most of the learning materials are provided online including examination; however, in engineering degrees, online learning has not seen much popularity due to its technical nature and laboratory components (Noor and Rahman, 2018).

3. Hydrology as a subject in engineering degrees

Engineers frequently apply water for many purposes. Especially civil engineers need to know the water properties in constructing infrastructure projects such as buildings, bridges and dams. Hence, all the universities offer a range of courses that provide engineering students to have specific knowledge about water. For example, a civil engineer needs to find out how much water will pass through a bridge for a given rainfall event. A mechanical engineer needs to know how to pump the water in a most cost-effective manner. Some of the common courses on water in civil engineering are Fluid Mechanics, Hydrology, Hydraulics, Water Resources Engineering, Statistical Hydrology and Wastewater Treatment This paper portrays the education systems and teaching/learning methods of Hydrology of three different universities of two different countries.

Hydrology is linked with many different disciplines and requires multiple dimensions of understanding (Wagener *et al*., 2010; Vogel *et al*., 2015). Hydrology contains many different aspects of water. By studying hydrology, we get to know the major aspects of water management e.g. quantity and quality of water over space and time.

The most common approach adopted in the University of Technology Sydney (UTS) and Western Sydney University (WSU) is the blended learning approach. Both universities allow students to interact with their teachers directly to gather knowledge also provide enough resources online as well as provide hands on experience. The students can also learn from their peers e.g. via group discussion and peer assessment.

The course in UTS allows the students to obtain knowledge on open channel hydraulics and hydrology in a common subject, but in WSU and BUET these are taught in two different subjects. In UTS, this subject teaches the students the use of HEC-RAS, FLIKE and RFFE models to analyze catchment systems for design flood estimation and management. It also teaches flood frequency analysis methods by using Excel and regional flood frequency (RFFE) method and some other flood estimation models and procedures.

The hydrology course offered in WSU focuses on surface water hydrology where water balance, flow routing, unit hydrograph, HEC-RAS modelling are covered. In WSU, there is another unit called Statistical Hydrology (an elective unit) which covers flood frequency analysis, RFFE and other statistical methods in another subject, groundwater hydrology is covered, which is also an elective unit. It seems WSU offers greater depth hydrology course for the students who would like to specialize in hydrology.

The hydrology course offered in Bangladesh University of Engineering & Technologies (BUET) mainly focuses on surface water hydrology, flood management and irrigation. Unlike the Australian universities BUET has adopted the passive learning approaches. There are ample opportunities for the students to learn from the tutors and from each other by doing case studies and group projects, but online resources are not as widespread as Australia.

But there are changes coming in the education system in BUET. Many scholars have proposed blended learning methods to be more effective in engineering. Kabir et al. (2008) state that most of the students cannot make link between mathematics and sciences they learnt as a freshman with the engineering courses as well as with their future careers in engineering, which leads to self-dissatisfaction. Teachers, who lack skills and knowledge, also act as a discouraging factor. Studies suggest that students doing their engineering courses are very inductive and their mentors are deductive (Felder et al., 1988). Their studies show that students need three fundamental tools to cope with the challenge of 21st century, which are knowledge, skill and attitude (Kabir et al., 2008). All these skills can be effectively gained from blended learning as it exposes the students to abundant source of resources and gives them the opportunity to learn in a more interactive and engaged ways. As a result, students are expected to be more confident and self-satisfied.

4. Flood frequency analysis

Flood frequency analysis (FFA) is one of the most important topics taught in Hydrology course. FFA is devoted to estimate design floods at a given location using recorded flood data. There are many issues in flood frequency analysis as explained in Haddad et al. (2011) which include data error (Haddad et al., 2010), selection of the parent probability distribution, parameter estimation method, uncertainty analysis and impacts of climate change on floods. This paper focuses on design flood estimation based on annual maximum flood data in 5 different stream gauging stations in South Australia. We will be using General Extreme Value distribution (GEV) and Gamma distribution to analyses the data and compare the differences in flood quantiles by these two different methods and discusses the difficulties in interpreting the results for a novice hydrologist/engineer.

5. Methodology

To carry out the FFA, we used the R software. 'R' is programming software that allows us to determine peak flow rate for different return periods, here we report for 2, 5, 10, 20, 50 & 100 years. There are different distributional functions that we can use in R to carry out FFA. However, we selected GEV and Gamma distributions as they are widely used in FFA. By using 'R' we first are able to visualize a histogram showing the AMF data over the years.
GEV is a three-parameter distribution. By using 'R' we can estimate its three parameters, location, scale and shape. The parameters are estimated by method of L moments in R. By using these parameters, we can obtain Q2, Q5, Q10, Q20, Q50 and Q100 (flood quantiles).

For the Gamma distribution, we need two-parameters as Gamma is a two-parameter distribution, namely Shape and Rate. After obtaining the Shape and Rate using 'R' we can estimate Q2, Q5, Q10, Q20, Q50 and Q100 using R.

6. Results

The parameters of the GEV distribution are shown in Table 1. It can be seen from Table 1 that the shape parameters show a wider variation from site to site although all the five catchments are from the same drainage basin (426). This implies GEV may not be appropriate for all the five sites.

Table 2 provides the parameters of the Gamma distribution. Here, the shape parameters show a wide variation from site to site, which indicate the Gamma distribution may not be suitable for all the sites. It should be noted that since the record lengths of the stations are not very high (in the range of 25 years to 38 years), the estimated shape parameters are expected to show some variability. Data extremes affect the shape parameter estimation significantly.

Table 1: Three parameters for GEV distribution for the selected stations

Station ID	Location	Scale	Shape
4260504	30.56760	20.30150	0.14220
4260529	7.031300	9.146200	0.51790
4260533	6.096000	22.26800	3.70300
4260557	15.58564	11.48943	0.01413
4260558	3.883000	5.179000	0.87600

Table 2: Two parameters for Gamma distribution for the selected stations

Station ID	Shape	Rate
4260504	2.344680000	.051707000
4260529	0.527471090	0.03025000
4260533	0.360424900	0.01310600
4260557	1.800235810	0.08017899
4260558	0.674939000	0.05170500

Station ID 4260504

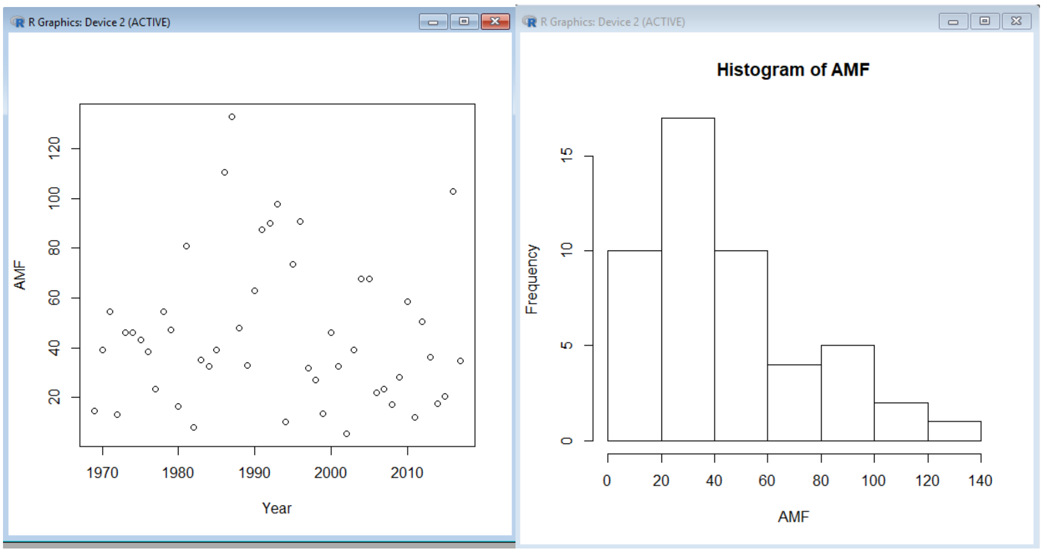

Figure 1 - Scatter plot & Histogram for station 4260504

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  Min.  1st Qu.  Median    Mean  3rd Qu.    Max.
 5.461   23.144  38.946  45.345   58.426 132.943
```

Figure 2 - Scatter plot & Histogram for station 4260504

Table 3: Quantile flow rates for station 4260504

4260504	Q2 (m3/s)	Q5 (m3/s)	Q10 (m3/s)	Q20 (m3/s)	Q50 (m3/s)	Q100 (m3/s)
GEV	38.21	64.51	84.41	105.60	136.46	162.41
Gamma	39.09	66.62	85.00	102.37	124.38	140.55
Percentage Variance (%)	2.31	3.27	0.69	-3.06	-8.85	-13.46

The scatter plot in Figure 1 shows the AMF over the years 1970-2010. The AMF data show a wider variation with many AMF values are quite small, however one flood is too high. The estimated quantiles by the GEV and Gamma distribution are provided in Table 3, where the two methods provide quite similar quantile estimates (with percentage difference in the range of 0.69 to 13.46). In FFA, these differences are acceptable. Hence it may be stated that for station 4260504 both the GEV and Gamma could be the parent distribution. However, advanced analysis such as Monte Carlo simulation and goodness of fit tests need to be applied to confirm this initial finding.

Station ID 4260529

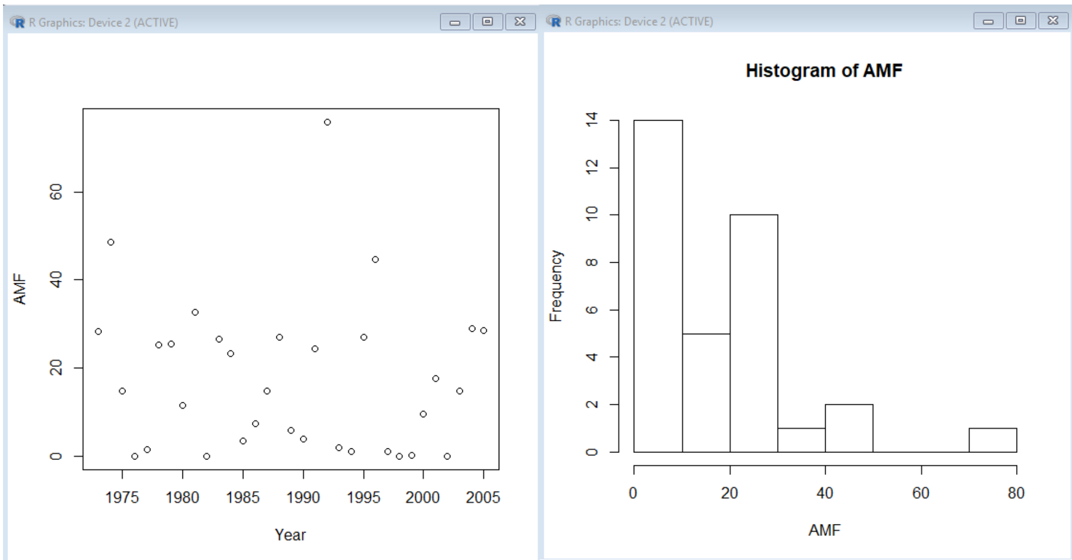

Figure 3: Scatter plot & Histogram for station 4260529 (AMF are in m^3/s)

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   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.0162  1.8276 14.7349 17.4367 26.9259 75.8102
```

Figure 4: Summary table for station 4260529

Table 4: Quantile flow rates for station 4260529

4260529	Q2 (m3/s)	Q5 (m3/s)	Q10 (m3/s)	Q20 (m3/s)	Q50 (m3/s)	Q100 (m3/s)
GEV	10.72	27.77	46.01	71.61	122.61	180.65
Gamma	8.31	28.69	46.65	65.72	91.97	112.37
Percentage Variance (%)	-22.54	3.31	1.38	-8.23	-24.99	-37.80

The flood quantiles for station 4260529 also showed similar results from two different distributions up to Q20 as shown in Table 4. However, Q50 and Q100 had a large relative difference. This shows that estimation of higher return period floods is not easy and more professional judgement is needed in selected higher return period flood, which are very much needed for large infrastructure project such as a large bridge.

Station ID 4260533

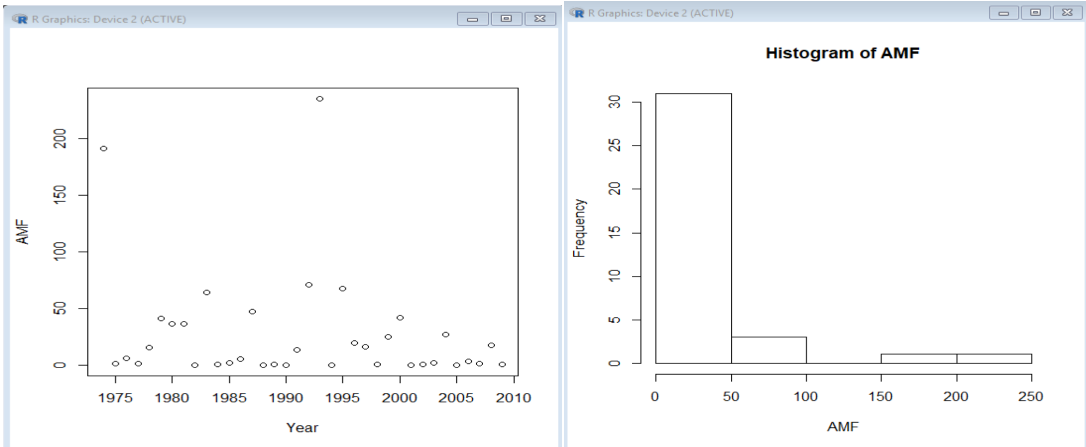

Figure 5: Scatter plot & Histogram for station 4260533

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
0.09028	0.49740	5.86632	27.49769	36.31655	234.73380

Figure 6: Summary table for station 4260533

Table 5: Quantile flow rates for station 4260533

4260533	Q2 (m3/s)	Q5 (m3/s)	Q10 (m3/s)	Q20 (m3/s)	Q50 (m3/s)	Q100 (m3/s)
GEV	23.45	1553.61	25012.25	359561.50	11329112	150332483
Gamma	8.77	43.75	79.05	118.41	174.28	218.50
Percentage Variance (%)	-62.58	-97.18	-99.68	-99.97	-100.00	-100.00

The scatter plot shows inconsistant AMF data in Figure 5, in particular, two AMF values are too high. From year 1990-1995, the AMF valueswere too high as shown in Figure 5. Because of that, GEV distribution showed some wired results that were too high in Table 5 (for Q100 it is 68 million times different). But Gamma distribution showed quite sensible results. This clearly shows the danger of using a single probability distribution in FFA, in this case use of Q100 from the GEV distribution will make the infrastructure too large costing a huge sum of money This case shows that a junior hydrology engineer may not make the right decision in FFA, the expert judgement by senior engineer is needed to make the right decision here.

Station ID 4260577

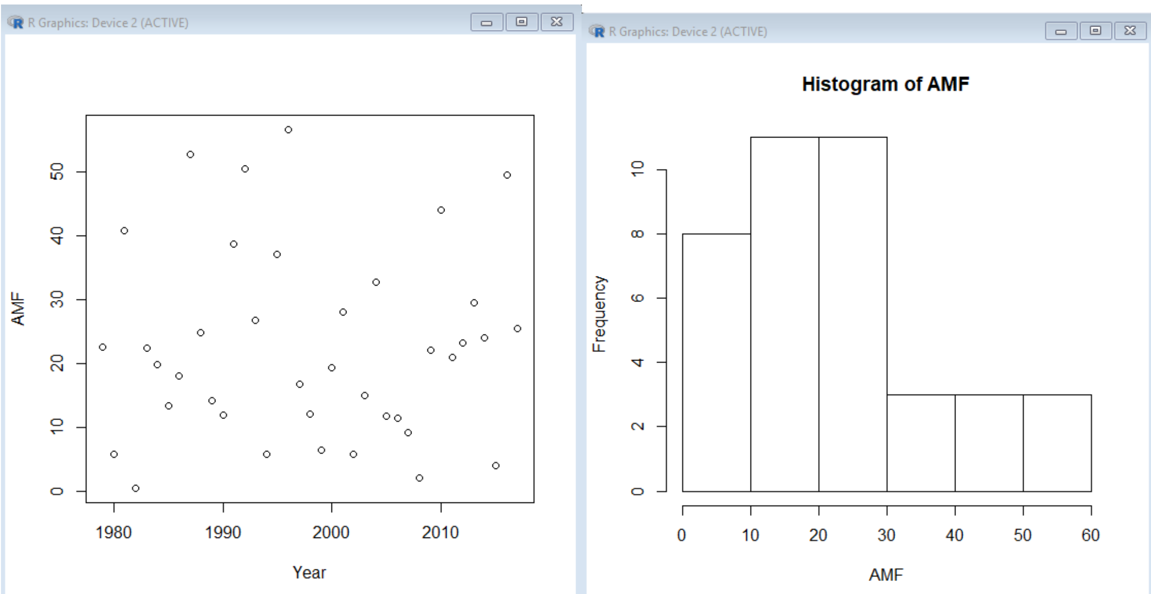

Figure 7: Scatter plot & Histogram for station 4260557

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  Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
0.5151 11.7760 20.9884 22.4526 28.8056 56.5810
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Figure 8: Summary table for station 4260557

Table 6: Quantile flow rates for station 4260557

4260557	Q2 (m3/s)	Q5(m3/s)	Q10(m3/s)	Q20(m3/s)	Q50(m3/s)	Q100(m3/s)
GEV	19.81	33.01	41.86	50.44	61.68	70.19
Gamma	18.46	34.03	44.77	55.08	68.30	78.09
Percentage Variance (%)	-6.80	3.12	6.96	9.20	10.75	11.25

For station 4260557 the AMF data showed a great consistancy in in Figure 7. As a result both GEV and Gamma distribution showed almost similar quantile estimates in Table 6. The variation between the quantile estimates was mostly less than 12% in Table 6, which is acceptable in FFA.

Station ID 4260558

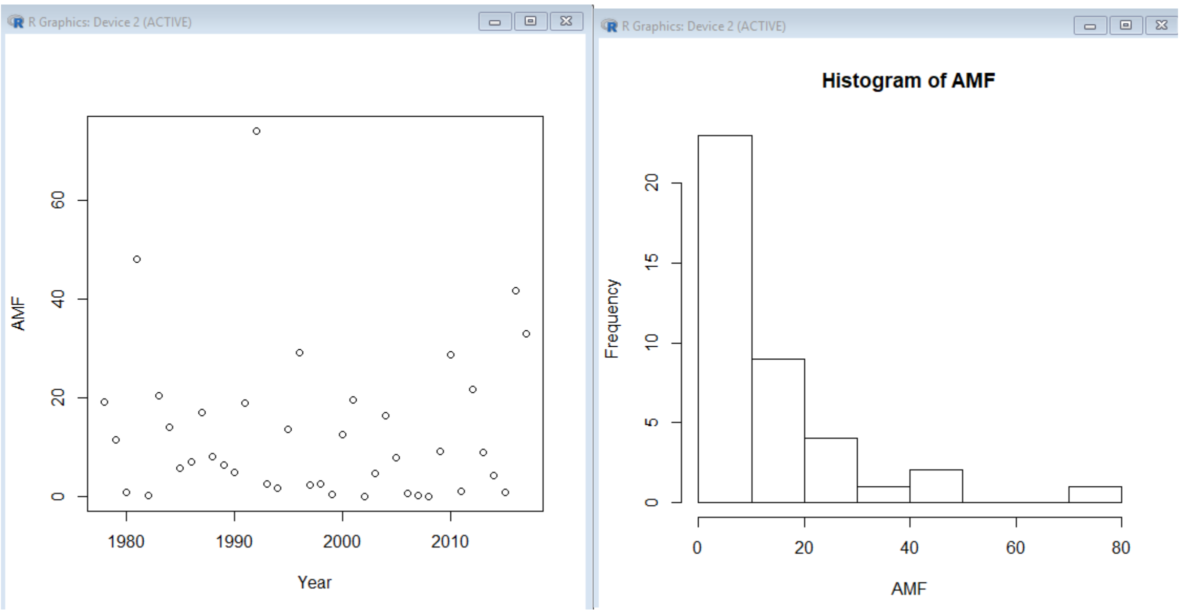

Figure 9: Scatter plot & Histogram for station 4260558

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
0.1169	2.2870	8.0480	13.0535	19.0854	74.0683

Figure 10: Summary table for station 4260558

Table 9: Quantile flow rates for station 4260558

4260558	Q2(m3/s)	Q5(m3/s)	Q10(m3/s)	Q20(m3/s)	Q50(m3/s)	Q100(m3/s)
GEV	6.12	19.97	40.42	77.72	178.36	330.50
Gamma	7.43	21.48	33.05	45.02	61.23	73.68
Percentage Variance (%)	21.37	7.57	-18.24	-42.08	-65.67	-77.71

For station 4260558 the flood quantile estimates were similar between Q2 to Q10 according to Table 9. But after that they showed a large difference Further study is needed to decide which of these two distributions provided more accurate results.

7. Discussion

We have used two different probability distributions to analyses the same AMF data set obtained from five different stations in South Australia. Even though the flood quantile estimates were not similar, the differences between the two methods are modest for most of the stations. Overall, it seems that Gamma is the preferred distribution for these catchments. It must be noted the GEV although widely used in Australia for rainfall and flood frequency analysis, it can provide very weird quantile estimates under certain cases.

The following lessons were learnt from this work experience by the first author from the fourth authors:

- Results from flood frequency analysis using a single probability distribution can give misleading results and design of infrastructure based on this result can be grossly under or over-estimated, which can increase flood damage or infrastructure cost many folds.
- Expert view is essential for learner engineers to interpret the results from flood frequency analysis.
- There are many other issues in FFA that need to be considered to recommend design floods for important/large infrastructure projects such as bridge, flood protection levees, freeway and dam spill way. Some of these issues include data accuracy (rating curve error, gaps in the data and data extremes/outliers), stationarity of the AMF flood data, parameter estimation method, goodness of fit test and uncertainty analysis by Monte Carlo simulation and boot strapping.

8. Conclusion

The purpose of this paper was to discuss the learnings of hydrology subjects in three different universities from a student's perspective and to analyse the flood data from South Australia using the flood frequency analysis, which is a common topic in hydrology course. We came to realise that Australian Universities are providing the students with the best learning approaches that is blended learning in teaching hydrology. This not only helps the students to learn to think out of the box, but also enhances their transferable skills such as teamwork, research skills and leadership skills. However, BUET is the leading engineering university in Bangladesh and continues to thrive despite having passive learning methods. But there is still room to grow as things are evolving for better in Bangladesh as they are adopting to more integrated learning methods (Kabir et al., 2008). In terms of flood frequency analysing of the data for five South Australia catchments, we have found that the application of a single probability distribution can produce very undesirable/grossly inaccurate results. But the knowledge acquired from the university courses was not adequate to interpret the results from this case study. However, the expertise of the third author assisted the other two authors to make the results more understandable. This perhaps indicates that engineering students need to work with the industry experts more closely, which has been happening more effectively with Australian universities. The universities in the developing countries still need to catching up in this regard to make their studies more interactive by inviting real world experts in their classrooms and sending their students to working with the industry experts as trainee engineers.

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Qatar Rainfall and Runoff Characteristics – A New Direction of Engineering Education and Practice in Qatar

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Abstract

Prompted by a rapid infrastructure development in recent years, the State of Qatar has developed a comprehensive national guideline titled Qatar Rainfall and Runoff Characteristics (QRRC) for estimation of design rainfall in Qatar. This guideline introduces more accurate rainfall characteristics that will be used as the bases to new world-class drainage standards that will contribute to a more resilient and safe storm water infrastructure for Qatar under a changing climate regime. QRRC was developed using rainfall data from over 30 stations located in Qatar and nearby Gulf countries. The method of L-moments was employed for derivation of new set of Intensity-duration-frequency (IDF) data for Qatar. This approach reduces the impacts of sampling variability on the analysis. It is intended that the QRRC will provide guidance and assistance to a wide range of entities including government agencies, developers, engineers, planners and policy makers. It is therefore of paramount importance that the recommended approaches and guidelines presented in QRRC be introduced in the undergraduate and graduate courses at the universities, including research and training centers in Qatar. This will assist in the preparation and training of young professionals for solving engineering problems in civil infrastructure, storm water design and hydrology. This paper presents important features of QRRC and how this can be used in tertiary education in Qatar.

Keywords: QRRC, Qatar, L Moments, floods, hydrology education

1. INTRODUCTION

Qatar is located in arid region of the Middle East, experiences little rain. The size of Qatar is 11,000 km². Less than 2% of the area is arable land and approximately 6% of the area is urban. The remaining area is desert. Rainy season which is locally known as Al Wasmi, mainly occurs in Qatar in the period from October to May, with significant inter-annual variability (Batanouny 1981). In Qatar, rainfall shows a higher degree of spatial and temporal variability with respect to intensity and duration (Bazaraa and Ahmed, 1991). The average annual rainfall values for Qatar are found to be in the range of 55.5–99 mm (Mamoon and Rahman, 2017). A sharp gradient in average annual rainfall was noticed, with north having higher values than the south.

Despite such a low rainfall, flash flooding is not uncommon in arid regions. Severe rainfall often causes flood damage to property, and even loss of lives. Severe flash flood in 1995 caused widespread damage in many Gulf countries including Qatar (Membery 1997). In the 2009 Jeddah flood there was 90mm of rainfall over 4 hours, which resulted in 122 deaths and the sweeping of over 3000 cars (arabnews).

Recent heavy rainfall events in Qatar caused widespread flooding of highways, underpasses and many parts of Doha city. The Department of Meteorology, Qatar recorded a maximum of 84 mm rainfall in Abu Hamour rainfall station on October 19, 2018 which has exceeded 1 in 100 year rainfall event as predicted in Qatar Rainfall and Runoff Characteristics (MME, 2018). Record rainfall and flash flooding since late October, 2018 also caused 12 fatalities in Jordan and one in Kuwait (floodlist.com).

As a host country of World Cup Football 2022, Qatar is undergoing rapid urban transformation defined by Qatar National Vision (QNV 2030) and Qatar National Development Strategy. To guide this on-going infrastructure development in the country, Qatar Government's Ministry of Municipality and Environment (MME) has carried out a comprehensive rainfall study for developing guidelines and standards for the design of storm and surface water infrastructure. New Intensity-Duration-Frequency (IDF) curves were developed by utilizing latest data, and impact of climate change in design rainfall estimation was also assessed.

Consequently, using the results and recommendations of his study, a single national guideline titled "Qatar Rainfall and Runoff Characteristics (QRRC)" was developed. The QRRC introduces new world-class drainage standards that will contribute to a more resilient and safe storm and surface water infrastructure for Qatar under a changing climate regime.

This paper presents some important features of QRRC and how these can be taught to engineering students in Qatar.

2. DEVELOPMENT OF QATAR RAINFALL AND RUNOFF CHARACTERISTICS GUIDELINES

The QRRC guideline is developed based on the results of a recently completed comprehensive rainfall study in Qatar (MME, 2017). The guidelines developed a rainfall and runoff design process as shown in Figure 1. The design process is initiated by locating the project area and is completed by determining the design hyetograph for a determination of flows.

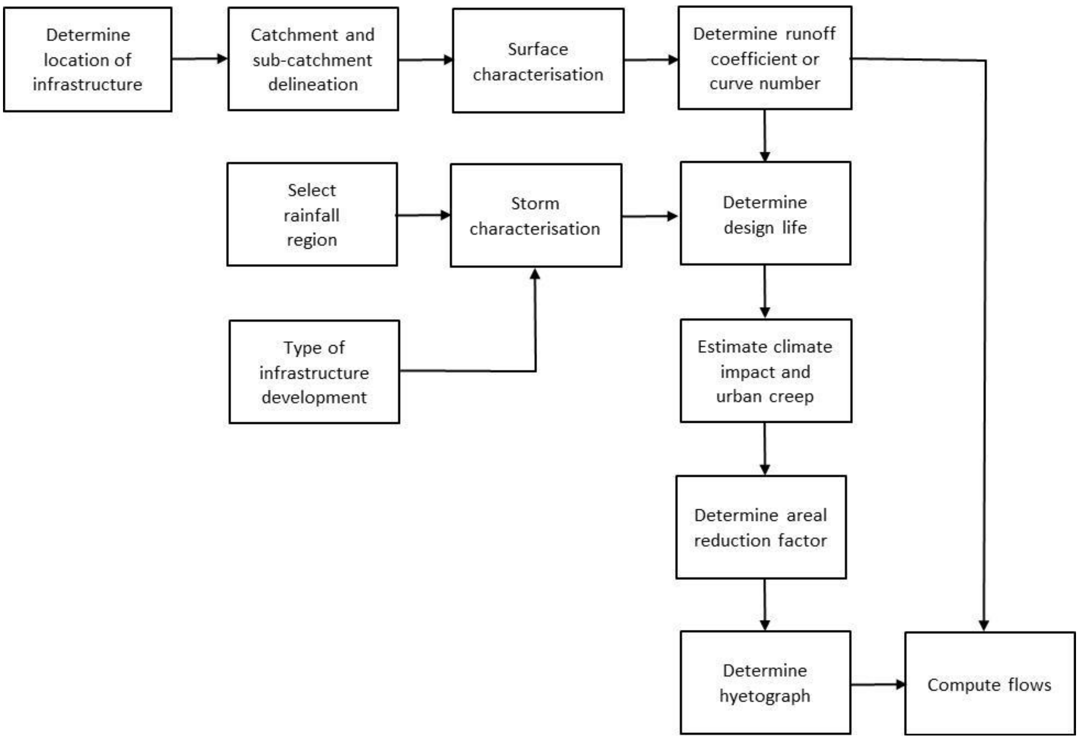

Figure 1. Overview of the rainfall and runoff design process

2.1 Determination of the location of Infrastructure & catchment delineation process

Catchment and sub-catchment delineation is based on topography. For smaller catchments, this process may be manual and based on topographical maps. For larger catchments, delineation is typically performed digitally, e.g. by loading a DEM (digital elevation model) into a GIS tool and performing an automatic delineation process. Catchment areas related to large projects may be located in more than one region. Conditions in the most demanding region will then govern the design. It is important to characterize rainfall events and storm durations accurately to quantify the drainage capacity required to handle the runoff.

Qatar is in an arid region with highly variable rainfall. The average of the annual maximum daily rainfall in the northern region is 26 mm; whilst in the southern region it is 21 mm. (Mamoon et al., 2014). For the purposes of drainage design, the different regions of Qatar shall be considered to have different rainfall characteristics. It is possible to define the rainfall and runoff design criteria with better precision by using the portal application (refer Section 3).

2.2 Intensity-Duration-Frequency (IDF) curves

The IDF relations are divided into two sections, a section for normal infrastructure with design criteria varying from 2 to 100 years ARI, derived from the L-moments method (Mamoon et al., 2014, Mamoon & Rahman, 2016).; and a second section for sensitive infrastructure with extreme IDF relations from 100 to 2,000 years ARI and based on LH-moments (MME, 2017).

A daily rainfall data from a total of 32 meteorological stations in Qatar, the surrounding neighbouring countries such as Bahrain and the United Arab Emirates were initially selected for deriving IDF relations in this study. The data period ranges from 1948 to 2015. The additional short duration rainfall data have also been used to derive rainfall distributions for short duration rainfall. Extensive quality control of collected rainfall data was carried out using several techniques that included application of double mass curve analysis, tests for record consistency between nearby gauges and discordance measurement tests. After applying the above criteria, only 23 stations were retained for the analysis. The locations of selected rain gauges are shown in Figure 2.
The IDF relation is derived from the following equation:

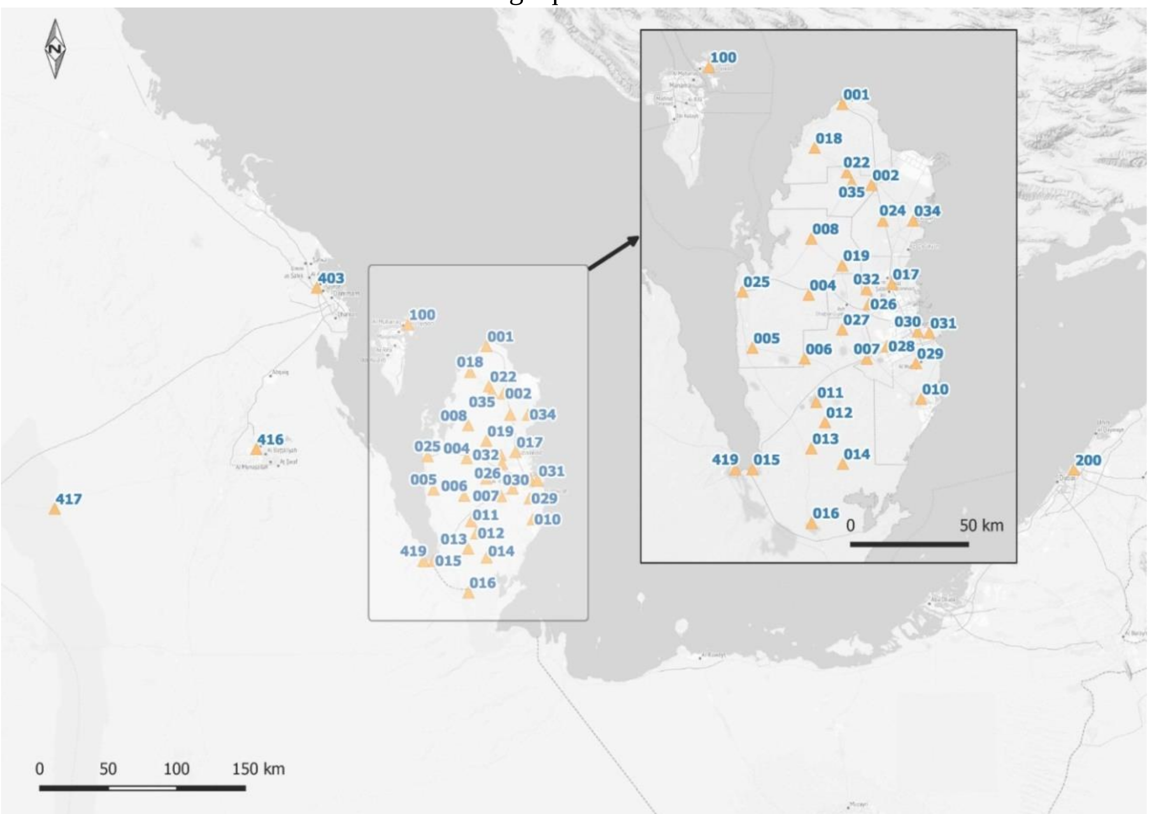

Figure 2. Location of the selected rain gauges considered in this study

$$i(T,t) = l_1 \alpha_D 24 \left\{ \frac{13.048 ln(T) + 12.72}{(t+11.4937)^{0.8853}} \right\} \tag{1}$$

where,

T = return period (years) – valid up to 100 years

t = duration of rainfall event (minutes)

$i(T,t)$ = rain intensity (mm/hour)

l_1 = average maximum annual 24 hour rainfall at site (mm/hour)

α_D = discretization adjustment factor (constant 1.151)

The rainfall design criteria can be expressed by the Rational Formula, with each region having different l1 values, where l1 is the average of the maximum annual 24-hour rainfall at site (in mm/hr). The discretization adjustment factor is set to 1.151, as evaluated in the Qatar Rainfall and Runoff Study (MME, 2017). IDF relation for central west region is shown in Figures 3.

Average rainfall in Qatar varies up to 30% more in the north than in the south. In order to compensate for the regional differences in rainfall, Qatar is divided into four regions - Northern, Central East, Central West, and Southern - each representing different IDF. Accordingly, the QRRC recommends that design IDF values should be extracted from the relevant figure dependent upon the location of the proposed development. The variation in rainfall within a region varies by 10-15%. Four regions are shown on Figure 4.

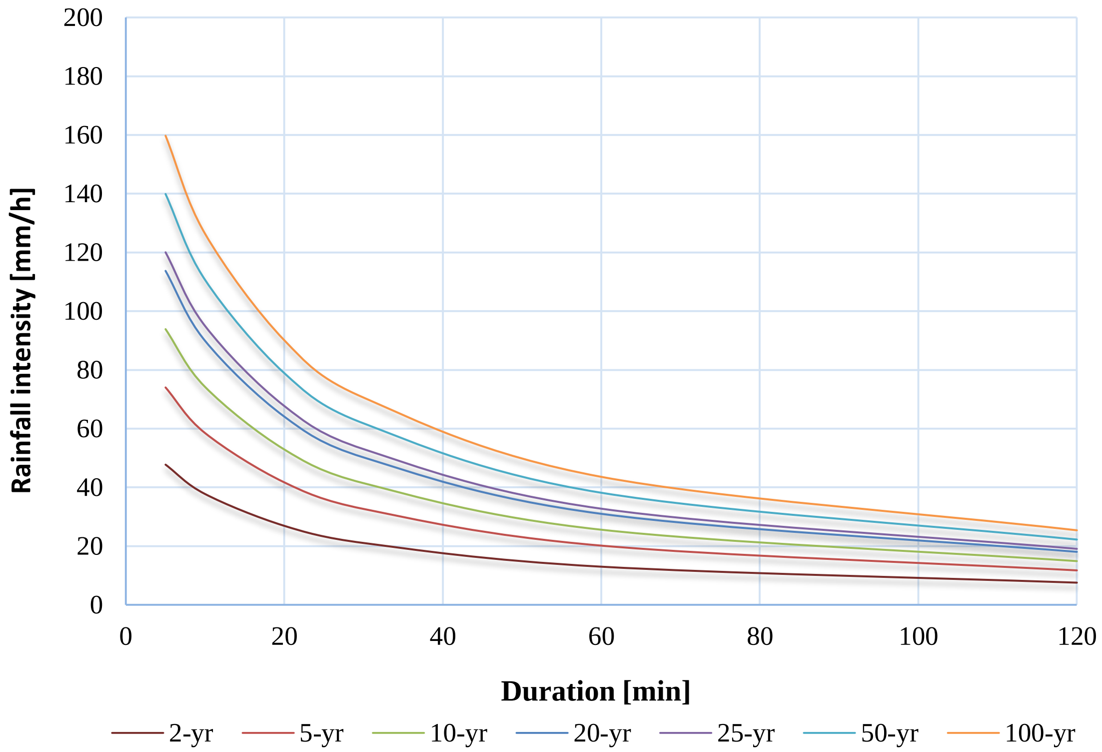

Figure 3. IDF relations for central west region (Doha) central east (Doha)

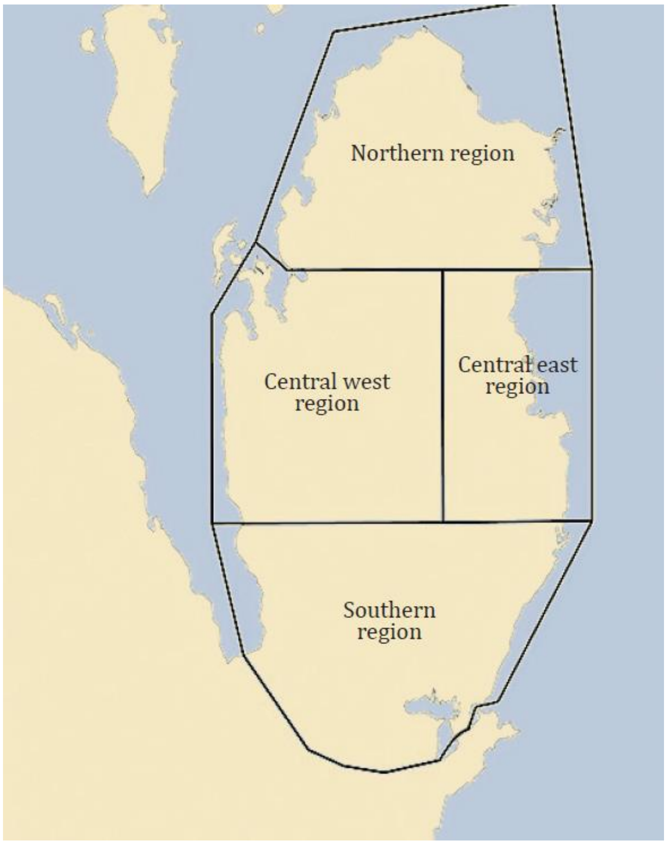

Figure 4. Division of Qatar into four rainfall regions

2.3 Catchment Characterization

When rain falls on a surface it may fill up the pores of the surface, infiltrate into the ground or flow as runoff to lower-lying areas where it is drained. It is important to investigate the hydrogeological conditions mainly infiltration and initial losses at each site. For large catchments, infiltration is determined by establishing the curve numbers based on land use and soil permeability. For small catchments, only initial losses are taken directly into account and infiltration losses are lumped into the runoff coefficients.

For smaller catchments, below 50 ha, the rational equation can be used to determine the flow. The flow of the surface runoff can be expressed by a simple relationship between the rainfall intensity, area and runoff coefficient. An initial loss may be deducted from the rainfall. The rational equation is:

$$Q = 0.00278\, C\, i\, A \qquad (2)$$

For catchments larger than 50 ha, the runoff curve number method should be applied and typically, in conjunction with modelling. Here the runoff is determined based on a curve number.

However, a catchment may consist of different types of surfaces. In this case, a weighted runoff coefficient is derived for the catchment. The equation for composite catchments is given as:

$$C_W = \frac{1}{A_{Tot}} \sum_{i=1}^{n} A_i C_i \qquad (3)$$

Where A_i is the area for surface type i, A_{Tot} is the total area, Ci is the runoff coefficient for surface type i, and C_w is the weighted runoff coefficient. Similarly, an average initial loss can be computed by the weight of each sub-catchment's areal contribution.

2.4 Type of infrastructure development

The storm water design criteria depend on the type of infrastructure development. Design criteria for road infrastructure are outlined in Table 1. However, Sensitive infrastructure, such as hospitals, civil defense, military installations or important transport infrastructure, may require higher flood protection levels than usual. The *LH*-moment method introduced by Wang (1997) is used, to derive the higher ARI's for guidelines for ARI to be used sensitive infrastructure is described in Table 2.

Table 1. Guideline for road classification and ARI to be used as design criterion.

CLASSIFICATION	RURAL OR URBAN	AVERAGE RECURRENCE INTERVAL
Parking	Rural or urban	2 years
Local road/Service road	Rural	2 years
Collector	Rural	2 years
Arterial	Rural	1 in 5 years
Expressway	Rural	1 in 10 years
Local road/Service road	Urban	1 in 5 years
Arterial	Urban	1 in 10 years
Expressway	Urban	1 in 10 years
Tunnels and underpasses	Urban	1 in 50 years

Table 2. Sensitive infrastructure

SECTOR	DESCRIPTION
Chemical plants	Chemical plants where flooding can cause environmental accidents, and plants vital to the community
Petrochemical plants	Petrochemical plants where flooding can cause environmental accidents, and plants vital to the community
Communication	Crucial communication equipment or communication centres, mobile

2.5 Storm Characterization

The design runoff is influenced by two time-related factors - climate change and urban creep. Climate change manifests itself as a higher variability and increased intensity of extreme rainfall events. The effect of urban creep is a loss of permeable surfaces due to urban growth. The increased imperviousness results in increased runoff.

Climate Change: Projects with a long design life must be resilient to a future climate, including the impact from extreme rainfall. Seasonal changes in rainfall can already be observed in historical data Mamoon and Rahman (2017). The uncertainty and vulnerability due to climate change has been taken into account through a climate change factor to be applied to the current IDF criteria. The climate change factor has been determined based on results from a selection of AR5 climate models. The models were selected based on various criteria, such as grid size and a comparison of observed data to near term simulations etc. (Mamoon et al., 2018). QRRC required that designers multiply the current rainfall intensity with the climate factor to derive the future rainfall.

Climate model results indicate that the climate change will already have its full impact in the year 2070. A linear interpolation is used to derive the climate factor for intermediate years from 2018 to

2070 (Figure 5). Future IDF curves were developed by applying the climate change factors to the current IDF curves. The climate change predictions are available on the portal and the user can determine future rainfall design curves from the current conditions up to year 2100.

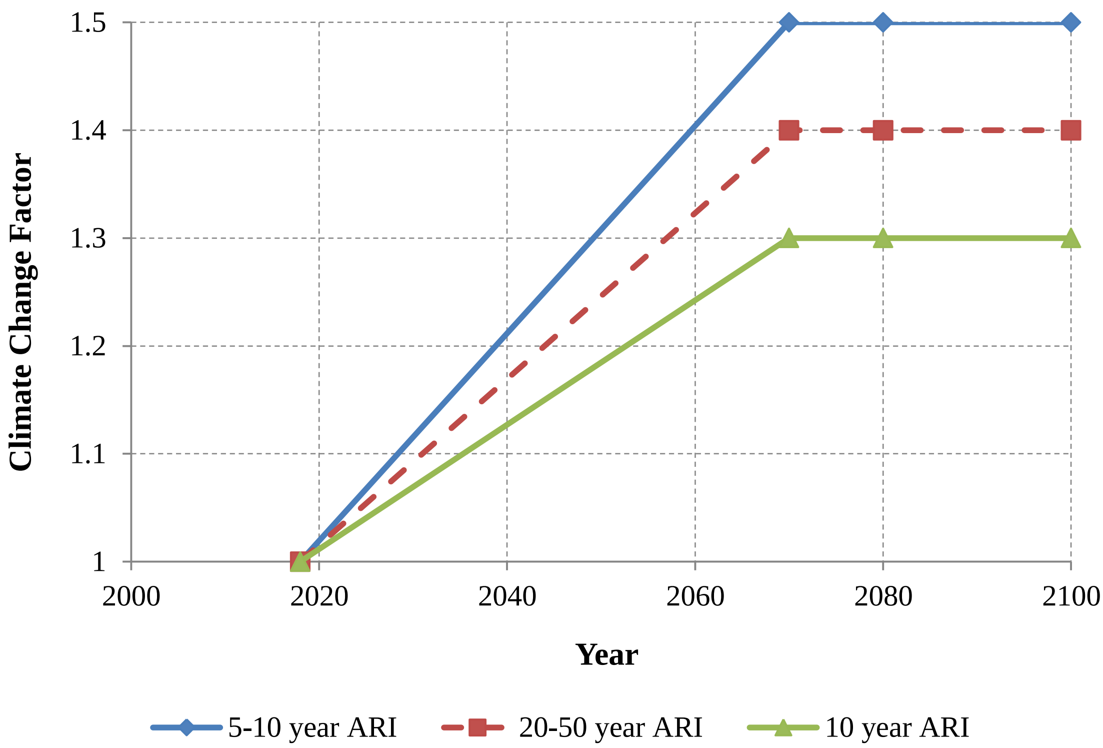

Figure 5. Climate change as a function of time and ARI

Urban creep: In Qatar, significant urban expansion is taking place at a rate that is likely to continue for the foreseeable future. To guard against infrastructure becoming outdated shortly after construction, an allowance for urban creep has been made into the road drainage design. The urban creep factor cannot exceed (1/runoff coefficient) or as a percentage cannot exceed [(1/runoff coefficient)-1]. For example, if the design horizon is 25 years and the runoff coefficient is 0.85, then the rainfall percentage increase is limited to [(1/0.85)-1] = 17.6%.

Table 3. Overview of urban creep (QHDM, 2017)

DESCRIPTION	DESIGN LIFE OF INFRASRUCTURE		
	10 years	**25 years**	**>=50 years**
Rainfall intensity percentage increase	+10%	+20%	+30%

2.6 Design hyetograph

A hyetograph is a graphical representation of the distribution of rainfall over time, which is used to understand the rainfall distribution for design storms. For a single catchment smaller than 50 ha, a simple uniform hyetograph can be applied. The intensity of the uniform hyetograph is defined by determining the design average recurrence interval T and considering the duration of the rainfall t to be equal to the time of concentration t_c of the catchment. The intensity derived from the IDF curve is then considered uniform in time and the rational formula is applied to derive the flow.

Large catchments are typically subdivided into sub-catchments. Modelling should be carried out, and the alternating blocking method (ABM) should be used to derive a hyetograph. The alternating block method is an approximation of the Chicago method, for the special case of r = 0.5 (Akan, 1993). Hyetograph plot for a 5 minute duration and 10-year ARI, the Central East Region of Qatar, using the alternating blocking method is shown in Figure 6.

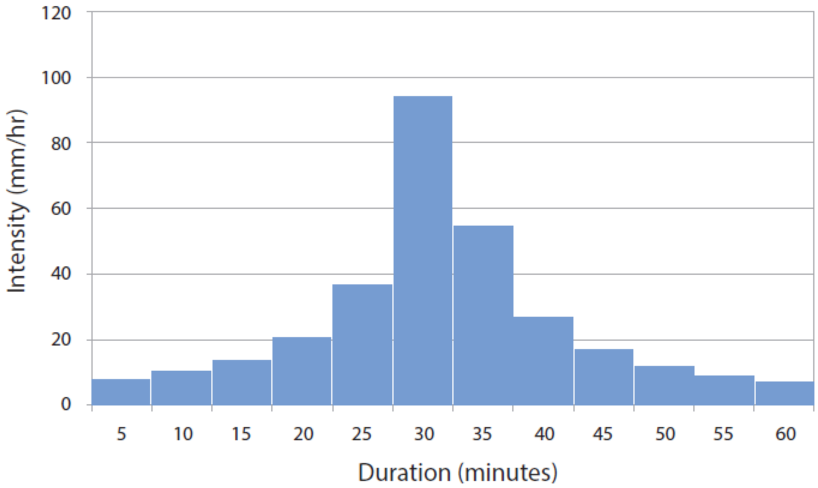

Figure 6. Hyetograph plot for 5 minute duration and 10 year ARI, Qatar, using alternating blocking method

3. IDF PORTAL

A smart IDF Portal has been developed to provide a precise IDF relation for any point or area in Qatar, typically a project location for urban development with a need for storm water infrastructure. Given that rainfall intensity and design curves show notable spatial variability in Qatar, an application such as the IDF portal that provides a precise estimation of the design rainfall as a function of the location and extent of the project can offer significant savings in terms of capital costs.

The design criteria are computed for cells of 5x5 km² size. This is the smallest unit for which rainfall design criteria are determined in the application. There are 840 cells in total, covering the entire Qatari Peninsula. The application can also provide future IDF relations based on derived climate change factors.

The elements of the interface consist of maps, buttons and different graphical elements. A snap shot of the graphical user interface is shown in Figure 7.

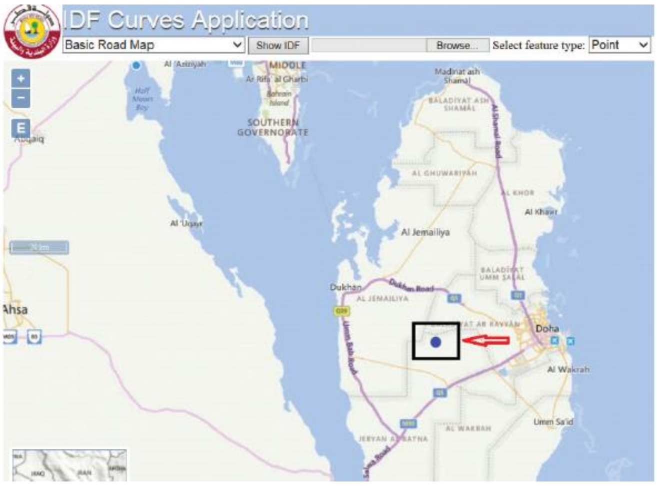

Figure 7 Browser displaying the IDF application

4. APPLICATION OF QRRC TO TERTIARY EDUCATION

To teach the engineering students the new IDF developed in Qatar as a part of QRRC, it is vital that all the engineering hydrology subjects in Qatari universities should include a lecture and tutorial class on this topic. In this regard, it is desirable to organize a seminar where all the hydrology and water engineering lecturers in Qatari universities should join in. For example, the Australian Rainfall and Runoff is a major part of Australian university's hydrology course, which has helped to develop a competent group of hydrologists/engineers in Australia. The teaching of QRRC to engineering students in Qatar will enable them to apply QRRC in practice with confidence. The teaching of QRRC can be made based on a student-centered such as blended learning approach (Rahman, 2017).

5. CONCLUSION

Qatar Ministry of Municipality and Environment has developed a national guideline tilted 'QRRC', for design of surface water infrastructure in Qatar and surrounding Gulf countries. The rainfall data with multiple temporal resolutions are used to derive new state-of-the-art rainfall and runoff characteristics for Qatari environment. The set of IDF curves presented in this guideline are based on a significant larger dataset consisting of 23 quality checked rain gauges from Qatar and surrounding Arabian Gulf countries. A regional frequency analysis method has been utilized for deriving IDF curves as described in Mamoon et al. (2014).

The guideline outlines the steps involved from deriving the design rainfall to computing the runoff flow rates and volumes based on the outcome from the Qatar Rainfall and Runoff study (MME, 2017). The guideline also applies to flood hazard evaluations, including events with high average recurrence intervals (ARI).

Climate change can affect the magnitude, frequency and spatial variability of rainfall. The updating of IDF curves is needed under a changing climate. Hence, this guideline also provides IDF curves incorporating possible impacts of climatic change and climate variability on rainfall data in Qatar, based on the latest IPCC.

A software application, the rainfall portal has also been developed that enables the user to select a project location and receive site specific IDF-relations. Given that the rainfall intensity and design curves show notable spatial variability in Qatar, an application such as the IDF portal that provides a precise estimation of the design rainfall as a function of the location and extent of the project can offer significant savings in terms of capital costs. The application can also provide future IDF relations based on derived climate change factors.

The guideline offers simple examples of how to compute the rainfall and flow from simple catchments. For larger projects, it is recommended to use numerical modelling to define the hydrological boundary conditions and characteristics as input into the models.

The preparation and training of engineers through academic courses and training is critical to solving major engineering challenges in planning and design of civil infrastructure, urban hydrology, estimating flows though urban drainage system, modeling, sustainability, and climate change. Hence, Qatari universities should include QRRC in their hydrology course curriculum.

6. ACKNOWLEDGEMENT

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Potential of Rainwater Harvesting in Greater Sydney: A Proposed Educational Tool for Sydney School Children

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Abstract

Rainwater harvesting (RWH) is recognised as a sustainable means to overcome water scarcity and cope with the climate change and variability. RWH can be an important supplementary source of water in parts of the world like Sydney in Australia where water demand is as high as 300 litres per person per day on average, which is very high compared to many developing countries. Due to higher water demand and environmental awareness, RWH systems have become very popular in Sydney in recent years. This study explores how rainwater can best be harvested across Sydney and how a school education tool can be developed to create water conservation awareness among school students in Sydney. In the data analysis, stations were used covering three study periods, 30 years (1986-2015), 50 years (1966-2015), and 70 years (1946-2015). Spatial and temporal analysis is done to demonstrate rainfall variability and potential of rainwater harvesting in Greater Sydney. This paper proposes an educational tool to be developed that can be used to identify the locations where more water can be saved within Sydney. Further research is continued to develop this tool in near future.

Keywords: Rainwater harvesting, spatial rainfall, climate change, rainwater tanks, Sydney

1. INTRODUCTION

Australia is the driest inhabited continents, and one of the highest drinking water consumers in the world (Preston 2009, Apostolidis et al., 2011). The increasing urban population and frequent droughts caused by climate variability and change have made water supply a major problem in Australia (Ryan et al., 2009). In recent years, a number of alternative water sources have received attention, which includes rainwater harvesting (RWH), grey water reuse and wastewater recycling (Zhang et al., 2010). Among these, rainwater harvesting has received the greatest attention as RWH has several advantages (Julius et al., 2013; Campisano et al., 2017; Mbilinyi et al., 2018).

Rainwater is a relatively clean source of water, and it is free when falling from sky. It is beneficial to harvest rainwater from roof catchments and use it for gardening. In addition, rainwater can supplement existing mains water supplies which saves treated water in the mains (Imteaz et al., 2013; Hajani and Rahman, 2014). RWH also reduces water supply costs, meets basic water needs and promotes the efficiency of environmental protection (Rahman et al., 2012; Dhakate et al., 2013). Australia has one of the highest degrees of the implementation of RWH systems. According to the results of a survey by the Australian Bureau of Statistics (ABS, 2015), about 1.7 million households had fitted rainwater tanks to their households. Due to water restrictions, increased awareness of the environment, government regulations and subsidies to install rainwater harvesting systems, rainwater harvesting has become popular in urban Australia. It can provide non - potable water for various needs, such as toilet flushing, washing, gardening and washing car (Rahman, 2017, Christian et al., 2016).

2. WATER CONSERVATION BY RWH

Water is the most vital resource on the earth required by all life forms, from micro-organisms to humans. Available freshwater continues to decline due to over-abstraction, pollution and reduced precipitation, resulting in a decrease in runoff (Ahammed et al., 2006). RWH is a very popular method for water conservation, particularly in urban areas. The harvesting of rainwater essentially means collecting rainwater on the building roofs and other impervious surfaces and storing it in a tank for later use. It can be an important primary source of water in parts of the world where supply of good quality drinking water is limited. Rainwater can be collected and stored from rooftops, land surfaces or rock catchments using simple techniques such as natural and/or artificial ponds and tanks. Such technologies are really important for countries where effective rainfall is available only for 3-4 months of the year when water can be stored in tanks for subsequent use (Chubaka, 2018).

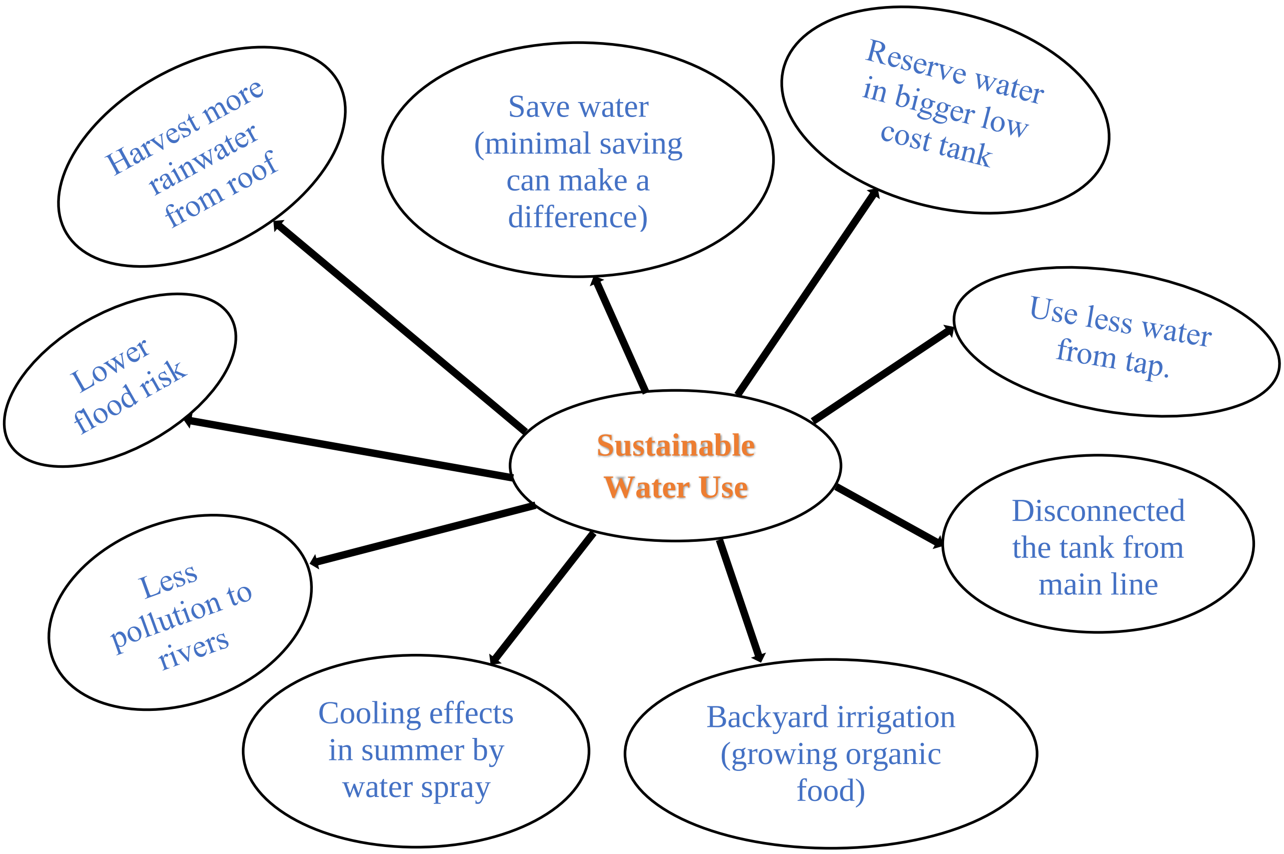

Figure 1: Sustainable water use by rainwater harvesting

Figure 1 discusses how harvested rainwater can potentially be used to enhance water and environmental sustainability. For example, rainwater can be used for flushing toilets, gardening, livestock, irrigation, drinking water (with treatment) and cooling at home in summer. Rainwater helps to reduce dependence on municipal water supplies, improve water efficiency by saving municipal water use and reduce the pressure on our water resources. It can also be used to recharge depleted groundwater. Rainwater is soft (pH 5.6) and is therefore ideal for cloth washing. The harvested rainwater can be used during water restrictions thereby offering more flexibility in water use and also helps to reduce our water bills. Rainwater harvested from roof tops and used locally has minimal greenhouse gas emissions compared to much higher carbon footprint from drinking water and other water supplies (e.g. greenhouse gases emission occurs during water abstraction, water treatment, water end use and waste water treatment). RWH can also reduce the flood risk by retaining part of the runoff. It captures part of the pollution load and helps to have clean water ways.

3. A PRELIMINARY STUDY ON RAINWATER AVAILABILITY IN SYDNEY

Initially 295 rainfall stations from Greater Sydney are considered, but only 29 stations have complete rainfall data without any gaps. Hence, these 29 stations, as shown in Figure 2, are used in this analysis. The daily rainfall data at each of these locations are obtained from the Australian Bureau of Meteorology. We use three study periods, 30 years (1986-2015), 50 years (1966-2015), and 70 years (1946-2015). Spatial locations of the selected 29 stations can be seen in Figure 2, while Table 1 provides the location, coordinates (latitude and longitude), data time series length, and average annual rainfall for the selected stations. The daily rainfall data were checked in a number of ways like missing data, consistency, visual inspections on excel plots, and checking all data analysed from FORTRAN program in excel. The daily rainfall values were categorized into four intensity groups as follows: light rainy days; heavy rainy days; moderate rainy days and extreme rainy days. All data analyses were done using FORTRAN program and graphs plotted in excel.

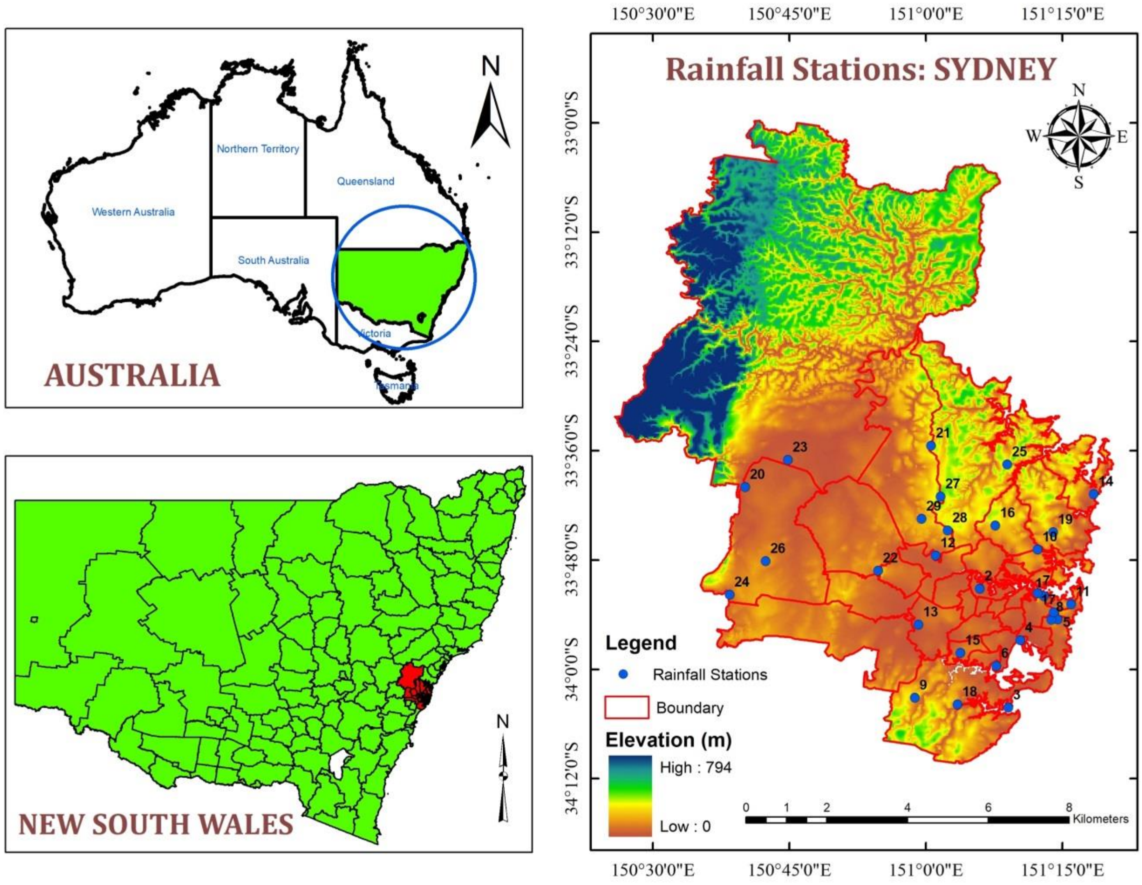

Figure 2: Location of the selected 29 rainfall stations in Greater Sydney

Table 1: Location, coordinates (latitude and longitude) and data length for the selected stations

S. No.	Station Number	Station Name	Latitude (degree)	Longitude (degree)	Period (daily)	Data Length (year)	Average Annual Rainfall (mm)
1	66006	Sydney Botanic Gardens	-33.8658	151.2161	1946 - 2015	70	1280.49
2	66013	Concord Golf Club	-33.8523	151.0985	1946 - 2015	70	1105.84
3	66014	Ronulla South Bowling Club	-34.0703	151.1512	1946 - 2015	70	1154.74
4	66037	Sydney Airport AMO	-33.9465	151.1731	1946 - 2015	70	1101.99
5	66052	Randwick (Randwick ST)	-33.9085	151.2417	1946 - 2015	70	1236.67
6	66058	Sans Souci (Public School)	-33.9942	151.1292	1946 - 2015	70	1139.69
7	66062	Sydney (Observatory Hill)	-33.8607	151.205	1946 - 2015	70	1252.68
8	66073	Randwick Race Course	-33.909	151.23	1946 - 2015	70	1320.46
9	66158	Turramurra	-33.7366	151.1271	1946 - 2015	70	1425.94
10	66160	Centennial Park	-33.8959	151.2341	1946 - 2015	70	1241.46
11	67002	Castlereagh	-33.6667	150.6696	1946 - 2015	70	895.16
12	67019	Prospect Reservoir	-33.8193	150.9127	1946 - 2015	70	919.12
13	67021	Richmond – UWS Hawkesbury	-33.6165	150.7477	1946 - 2015	70	858.33
14	66078	Lucas Heights (ANSTO)	-34.0517	150.98	1966 - 2015	50	995.88
15	66080	Castle Love	-33.7809	151.2044	1966 - 2015	50	1298.33
16	66124	Parramatta North	-33.7917	151.0181	1966 - 2015	50	965.64
17	66182	Frenchs Forest	-33.7493	151.2334	1966 - 2015	50	1324.69
18	67010	Glenorie	-33.5908	151.0094	1966 - 2015	50	962.45
19	67052	Berowra (Goodwyn Road)	-33.625	151.1491	1966 - 2015	50	1185.21
20	67089	West Pennant Hills	-33.7459	151.0402	1966 - 2015	50	1060.86
21	67029	Wallacia Post Office	-33.8637	150.641	1966 - 2015	50	810.63
22	66098	Rose Bay (Royal Sydney Golf Club)	-33.8809	151.2658	1986 - 2015	30	1250.82
23	66137	Bankstown Airport	-33.9181	150.9864	1986 -	30	846.96

		AWS			2015		
24	66141	Mona Vale Golf Club	-336795	151.3076	1986 - 2015	30	1088.93
25	66148	Peakhurst Golf Club	-33.9699	151.0635	1986 - 2015	30	958.69
26	66176	Audley	-34.0642	151.0578	1986 - 2015	30	1197.51
27	67084	Orchard Hills	-33.802	151.7069	1986 - 2015	30	766.97
28	67086	Dural	-33.6837	151.0273	1986 - 2015	30	1029.14
29	67100	Castle Hill (Kathleen Ave)	-33.7248	150.992	1986 - 2015	30	960.19

4. RESULTS AND DISCUSSION

Sydney's rainfall is strongly seasonal in character, generally more uniform throughout the year compared to other parts of Australia. Figure 3 shows the average annual rainfall of all the selected stations for three study periods 30 years (1986-2015), 50 years (1966-2015) and 70 years (1946-2015). Daily rainfall data have been processed to produce the average for each month by the developed FORTRAN program. A yearly average for rainfall has been calculated using the monthly averages. A total annual rainfall has been calculated by adding up all twelve months for the 30, 50 and 70 years. It is clear that some locations, such as Rose Bay, Bankstown, Mona Vale, Peakhurst, Audley, Orchard Hills, Dural and Castle Hill do not have longer data length (i.e. 50 and 70 years long data series are missing). It is found that the northern region of Sydney has higher annual rainfall, while western region shows lower rainfall. Daily rainfall data have been processed to produce the average for each month in FORTRAN 90. A yearly average for rainfall has been calculated using the monthly averages.

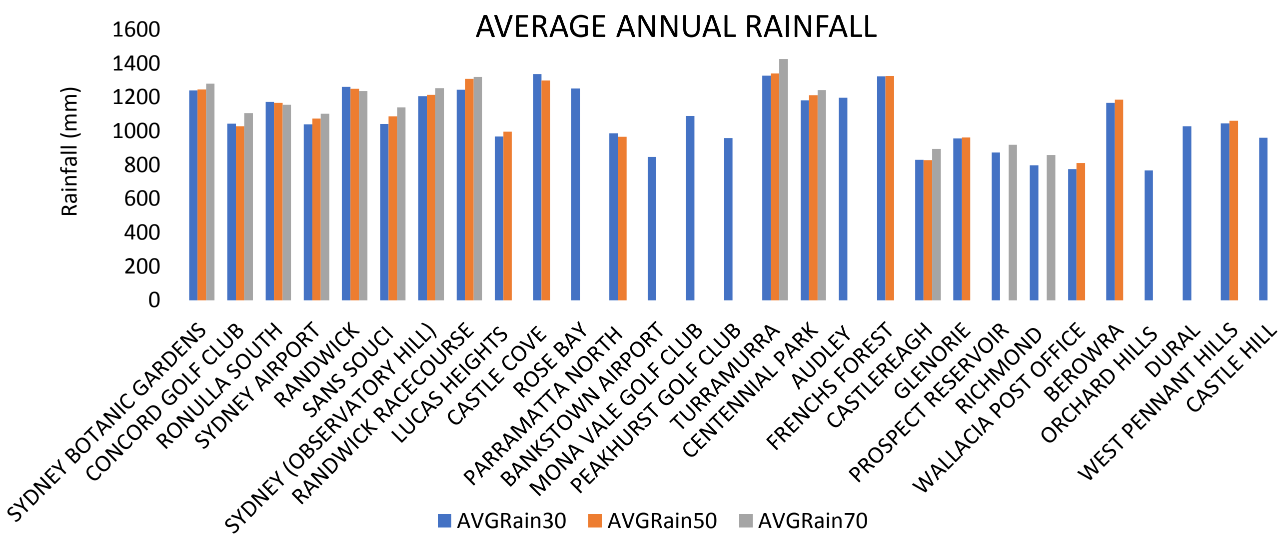

Figure 3: Average annual rainfall of 29 selected rainfall stations for 30, 50 and 70 years data length

Figure 4 shows average monthly rainfall considering all the 29 stations. As shown in Figure 4, most of the winter months (July, August and September) have smaller rainfall, while summer time (January, February, March, April and June) show higher rainfall. This means that the rainfall during the winter is less, so we need to harvest more rainwater and therefore we need a larger tank size. But the water demand in winter is generally smaller which will discount the tank size.

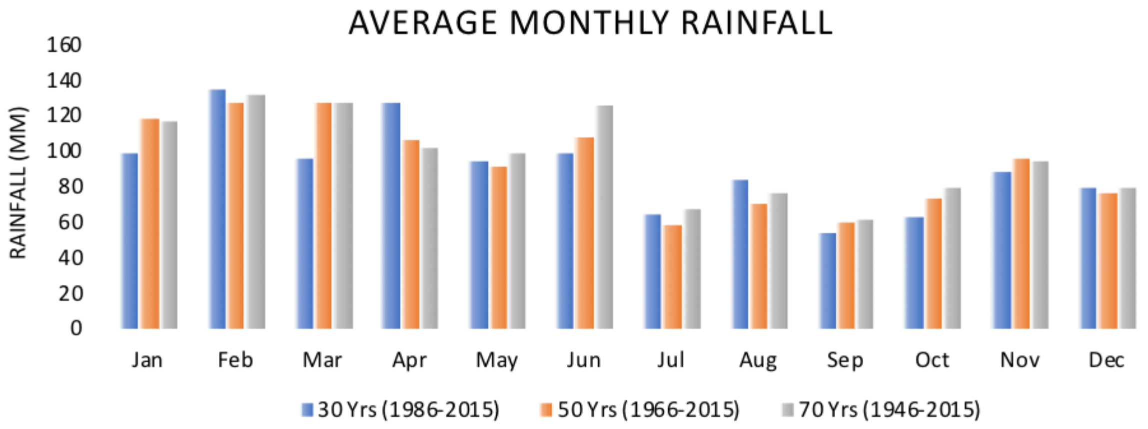

Figure 4: Average monthly rainfall for 30, 50 and 70 years

Figure 4 shows the average annual number of rainy days: light rainy days, moderate rainy days, heavy rainy days, and extreme rainy days. On average, only 8% of the days are moderate, heavy and extreme rainfall out of the 365 days in a year. In these days, irrigation from rainwater tanks may not be necessary, but for other days, irrigation may be needed and hence if tank is to be used for gardening/irrigation, a bigger tank will be needed.

Figure 5 shows minimum, maximum and percentage difference in mean annual rainfall values for five stations. The minimum rainfall observed is 766.97 mm at Orchard Hills rainfall station in western part of Sydney, while maximum rainfall is 1425.94 mm at Turramurra rainfall station (this represents 85% variation).

Table 3 shows that the mean annual rainfall in Sydney considering all the 29 stations are in the range of 1066 to 1148 mm, and the average number of rainy days are in the range of 112 to 116. However, there is a big spatial variation with smaller rainfall in the western Sydney and higher rainfall in the Northern Sydney.

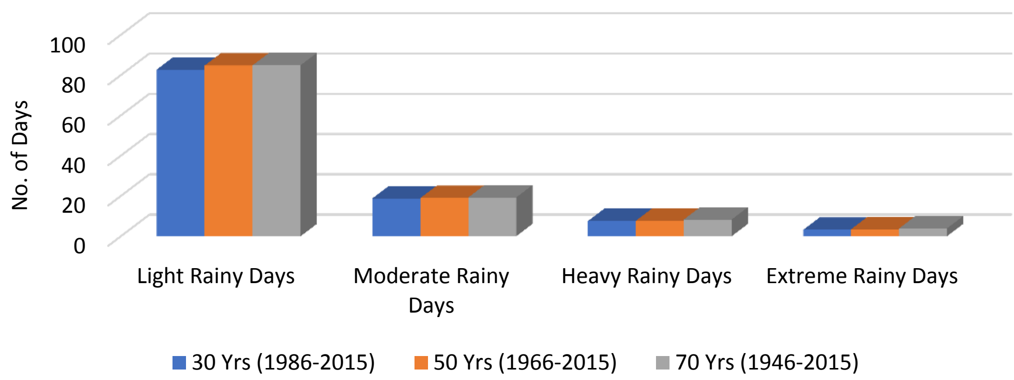

Figure 5: Average rainy days for 30, 50 and 70 years

Figure 6 exhibits how rainfall varies across Sydney. The highest rainfall occurs in the coast and in the north eastern part of Sydney. The lowest rainfall is found in the west and south-western part of Sydney. This figure can guide us where more rainfall can be harvested and/or where we need a bigger rainwater tank to meet a given water demand.

Table 2: Minimum and maximum rainfall values across Sydney (5 stations with the lowest and 5 stations with the highest rainfall)

Station Number	**Minimum Rainfall(mm)**	**Station Number**	**Maximum Rainfall (mm)**	**Percentage difference between minimum & maximum**
67084	766.97	66158	1425.94	85.92
67029	810.63	66182	1324.69	67.02
66137	846.96	66073	1320.46	61.73
67021	858.33	66080	1298.33	57.37
67002	895.16	66062	1252.68	46.61

Table 3: Important rainfall statistics

Data Series	**Mean Annual Rainfall**	**Mean Annual Rainy Days**
30 Years (1986-2015)	1066 ± 174.82	112.47 ± 13.09
50 Years (1966-2015)	1097 ± 175.72	115.01 ± 13.08
70 Years (1946-2015)	1148.71 ± 172.25	116.32 ± 15.20

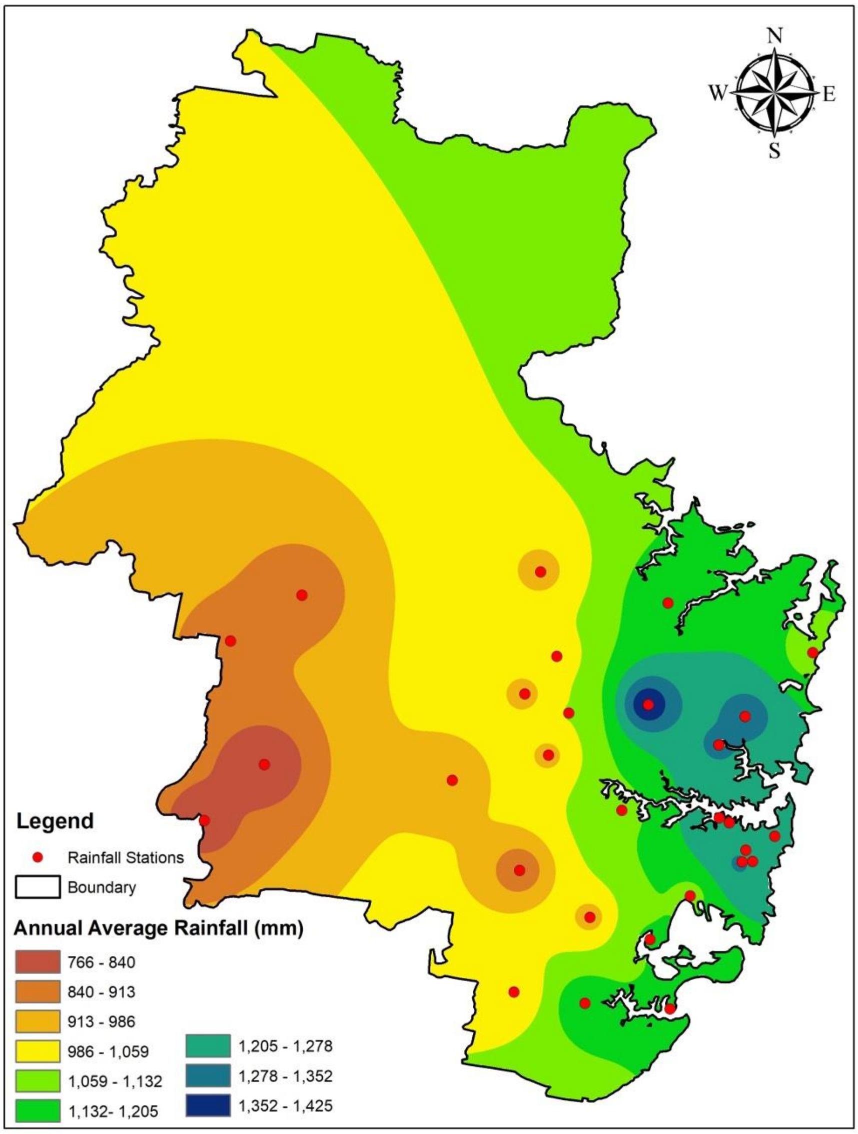

Figure 6: Spatial distribution of mean annual rainfall across Greater Sydney

5. EDUCATION TOOL DEVELOPMENT FOR RAINWATER HARVESTING

It can be seen from the previous section that Sydney has a highly variable rainfall regime where western part receives as little as 766 mm of mean annual rainfall, but the Northern part receives as high as 1425 mm. This implies that one needs a bigger tank in the western Sydney region to meet a given water demand compared with the northern part. Also, the temperature in western Sydney is higher than the coastal part, and the higher the temperature the higher the water demand, which means a larger tank size in western Sydney. To demonstrate these differences and how water savings by RWH vary over different parts of Sydney, it is proposed to develop a “rainwater tank game (RTG)” which will be able to generate rainfall data, calculate tank size, water savings and water spillage from the tank (if the water is not stored) at any location in Greater Sydney. The proposed RTG will have high level visual effects so that the school children love it. It will help to develop water conservation and environmental awareness among school children.

Some important elements of this RTG will be:

- The user can simulate rainfall of different intensity and duration at a given location in Sydney to mimic local Sydney rainfall.
- The user can simulate RWH system with different roof area, roof type, tank size and configuration.
- The user can generate runoff, water savings and spillage from the tank of different sizes.
- The user can play with different water usages e.g. toilet flushing, car washing, gardening and drinking water production.
- The user can simulate financial, ecological and environmental benefits e.g. how much flood control effect RWH can provide, how much pollutants can be captured by the tanks so that waterways get cleaner, and how much money is saved by considering the total benefits from a RWH system.

6. CONCLUSION

In this research, daily rainfall data from 29 selected rainfall stations in Greater Sydney (for 30 years, 50 years and 70 years' data lengths) are used to evaluate the rainwater harvesting potential. It is found that winter season (July to October) rainfall is quite low, which means we need a bigger tank size to meet the water demand. The minimum annual rainfall values are in the range of 700 to 800 mm (mainly in the western region), and maximum rainfall values are in the range of 1200 to 1400 mm (mainly in the northern region). There is a sharp rainfall gradient across Greater Sydney and hence a single rainwater tank size may not be providing the best water saving outcome in Sydney. As a part of this doctoral research, a RWH game tool will be developed for use by Sydney school children so that they get experiences in designing rainwater tanks of different sizes with different water savings, reliability and financial outcomes. This will create a positive image in the minds of the school children on water conservation and environmental values of ecosystems.

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Project-Based Learning in Engineering: Study of Renewable Energy Targets

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Abstract

In this paper, we describe the outcomes of a project-based engineering learning exercise undertaken by students to study the need for a country or a region to introduce policies on limiting the use of fossil-fuel based energy which has become a high priority. The specific task was to determine if achieving renewable energy goal of the jurisdiction was feasible in the short-term and the long-term. The students choose to carry-out projects of varying depth and complexity while meeting the same learning targets. The results of a sample project are given.

Keywords: Renewable energy targets, energy demand, energy policy, problem-based learning

1. INTRODUCTION

The engineering profession is changing, and so must engineering education. In many engineering schools, little has changed from the lecture, tutorial and hands-on laboratory dominated curriculum model. Engineering curricula need to change as academics take up general pedagogical ideas and respond to technological and operational challenges. In Australia, the number of students undertaking project-based units has proliferated while the academic staff numbers have remained stable. Supervising multiple final year projects by the same academic has become the norm at almost all tertiary institutions. For quality maintenance, it is essential that the workload related to project supervision be well-managed while at the same time ensuring that the learning targets have been met. In this paper, we describe an example of the use of project-based learning into an assigned task in electrical engineering during the fourth and final year of an accredited bachelor of engineering course.

In this study, the same project task was allocated to multiple students to be completed within 28 weeks. The task is described as "Study the need for a country or a region to introduce policies on limiting the use of fossil-fuel based energy which has become a high priority owing to climate change and global warming concerns. Determine if achieving renewable energy goal of the jurisdiction is feasible in the short-term and the long-term." The following research questions were posed by the students.

1.1. Research Questions

- Will the country or the region meet its energy targets in short-term and long-term?
- Will the demand for energy outgrow the ability of generation?
- Will the country be able to meet its carbon reduction targets in short-term and long-term?
- What are the various models that have been used to predict energy generation & consumption?
- How to improve the existing energy generation, consumption and carbon emission models?
- Will the proposed models in the project serve as improvements to existing models?

1.2. Research Objectives

- A model of the energy generation and consumption of the country in short- and long-term.
- A model of renewable energy generation in short-term and long-term.
- An improved model to predict energy consumption of the region in short- and long-term.
- Recommendations for solutions based on results from the models.

In the section below, the summary of a completed project report is presented. This student selected one small region (state) of a country (Australia) to model renewable energy targets, energy generation, and supply and demand. The developed model can potentially be used to assess renewable energy targets for other similar regions and countries.

2. SAMPLE PROJECT: FEASIBILITY OF AUSTRALIA MEETING SHORT- AND LONG-TERM RENEWABLE ENERGY TARGETS

In 2016, 81% of the world's energy was generated from non-renewable fossil fuels [1]. Concerns have been raised globally about the use of fossil fuels for energy, due to their finite nature and contribution to human- induced climate change. The Intergovernmental Panel on Climate Change (IPCC) has noted that the largest contributor to climate change is the burning of coal, oil and natural gas for energy, with 32,077 Mt of CO2 emissions produced in 2014 [2]. In 2015, Australia signed the Paris Agreement, setting a target to reduce carbon dioxide emissions to 26 – 28% of the 2005 level by 2030 in the aim to tackle climate change [3]. To achieve this, in 2015 the Australian Government reformed the Renewable Energy (Electricity) Act 2000 (Cwlth), setting a target of 23.5% or 33,000 GWh of Australia's energy to be generated from renewable sources by 2020. With less than 18 months remaining, Australia is on track to meet its Renewable Energy Target (RET) [4]. However, there are concerns that without federal policy extending beyond 2020, Australia will not meet its emissions reduction targets. Many of the states and territories within Australia have developed policies supporting the RET, aiming to address the lack of federal energy policy after 2020 [4]. South Australia is notable for its renewable energy policy, with a target of 50% of the state's electricity supply to be generated by renewable energy sources by 2025 [4]. The closure of the Northern coal-fired power plant in 2016 meant that South Australia met this target eight years ahead of schedule [5]. The question remains as to what South Australia's energy mix will be composed of in 2025, and beyond this to 2050. This paper aims to predict South Australia's energy mix in 2025 and 2050, as a model for whether Australia will be able to meet its renewable energy and emissions reduction targets.

2.1 Renewable Energy Technologies

Australia's use of renewable energy relies heavily on three technologies: hydro, solar and wind. Most of Australia's hydroelectricity is generated by the Snowy River Hydro Scheme in NSW and Tasmania's network of hydropower plants, which feed into the National Energy Market (NEM) for use by other states [4]. South Australia does not have the water bodies to take advantage of hydroelectricity compared to other states in the NEM. Wind power and solar photovoltaic (PV) energy have the greatest potential application in South Australia and contribute significantly to Australia's renewable energy generation [4]. Australia has considerable capacity for the development and use of solar PV energy, with the annual solar radiation that Australia receives being approximately 10,000 times our consumption [6]. Wind is consistent in South Australia, making it a good location for the development of wind farms [7]. The largest limitation to both solar PV and wind power is that they are intermittent – the amount of electricity generated cannot be guaranteed, and the availability of electricity may not be adequate during peak times [8].

2.2. Potential Role of Future Technologies

Smart Grids, Electric Vehicles (EVs) and energy storage have considerable potential to impact Australia's energy network in the future. Smart Grids allow for the integration of renewable energy technology into the electricity grid at any point, and it has been argued that they are essential to future energy systems [9, 10]. Smart Grids can be further integrated with EVs through vehicle-to-grid technology [11]. In vehicle-to-grid systems, EVs can be charged in off-peak times, making use of excess load, and then feed back into the grid during peak times when not in use. By being able to better facilitate the connection of renewable energy into the electricity supply system, Smart Grids can significantly reduce the environmental impact of the entire grid [12]. The development of energy storage technology can stabilise renewable electricity use by storing generated power for use at a later time. The development of battery storage technologies allows for the accumulation of energy in off-peak hours or when there is excess renewable energy produced to be used during peak times [13]. Battery storage can be used in conjunction with intermittent renewable energy generators to manage the supply- demand balance [14]. The construction of the Tesla lithium-ion battery storage project at Hornsdale Wind Farm in South Australia in 2017 saw one of the first uses of this technology in Australia to stabilise the use of renewable energy generation [15].

2.3. Future of Renewable Energy Generation

The use of renewable energy as a key source of electricity generation in Australia is increasing and is projected to continue in the coming years. Globally, the construction of renewable energy generators has overtaken the construction of coal, natural gas and oil generators in 2015 [4]. Analysis by Bloomberg New Energy Finance (BNEF) in 2017 found that the cost of constructing new renewable energy generation plants in Australia is cheaper than constructing coal-fired power stations, and at a similar cost to combined-cycle gas turbine generators [4]. According to the same report, the cost of renewable energy generators after construction is significantly less than a combined-cycle gas generator as there is no price of fuel to be accommodated for, making renewables the most economical option for Australia’s future. These analyses generally apply to the South Australian energy sector which is the main subject of this work.

3. PROJECT METHODOLOGY

To determine South Australia’s potential energy mix in 2025 and 2050, future energy demand, the role of existing energy generators and the commissioning of new energy generators must be considered. Data were collected from statistics published by the Australian Bureau of Statistics (ABS), the Australian Energy Regulator (AER) and the Australian Energy Market Operator (AEMO), as well as from publicly available information published by individual power stations in South Australia, Finkel et al, and Gerardi and Galanis [16-20]. The research questions listed in Sec. 1.1 directed this literature-based study. All secondary sources of data available at the time of study (Oct 2018) were consulted in arriving at the model for energy generation and consumption.

4. PREDICTION MODEL AND DISCUSSION

Population and energy demand trends from published data were calculated to predict the demand for electricity in 2025 and 2050. Using data from the ABS, South Australia’s projected population in 2025 and 2050 was determined by:

$$PR = \frac{(Pop_{Present} - Pop_{Past})}{Pop_{Past}} \times 100 \tag{1}$$

where, PR is the per cent rate of population change, $Pop_{Present}$ represents the current population, and Pop_{Past} represents the past population. From this, the projected population of South Australia could be calculated (2), where n represents the number of periods (years) and Pop_{Future} represents the projected future population.

$$Pop_{Future} = Pop_{Present} \times (1 + PR)^n \tag{2}$$

As can be seen in Fig. 1, South Australia’s population is projected to reach 1,852,035 in 2025 and 2,200,768 in 2050, respectively.

Data gathered from the AER for South Australia’s winter and summer peak energy demand between 1998 and 2018 was then compared to South Australia’s population. Energy demand per capita was determined and a trend line calculated by:

$$Y=mX+b, \text{ where} \tag{3}$$

$$\hat{X}=\frac{1}{n}\sum_{i=1}^{n}x_i \text{ (The average of x)} \tag{4}$$

$$\hat{Y}=\frac{1}{n}\sum_{i=1}^{n}y_i \text{ (The average of y)} \tag{5}$$

$$m=\frac{\Sigma_{i=1}^{n}(x_i-\hat{X})(y_i-\hat{Y})}{\Sigma_{i=1}^{n}(x_i-\hat{X})^2} \tag{6}$$

$$b=\hat{Y}-m\hat{X} \tag{7}$$

The energy demand versus population trend was calculated for winter (8) and summer (9).

$$Y=0.007\times X+1302.2 \tag{8}$$

$$Y=0.0012\times X+1061.7 \tag{9}$$

From this information, Fig. 2 graphs the trend using the projected population in 2025 and 2050.

As can be seen in Fig. 2, South Australia’s energy demand is projected to rise to about 2598 MW in the winter of 2025 and 3284 MW in the 2025/26 summer. By the winter of 2050, the energy demand is projected to be 2842 MW, and by summer 2050/51 demand will peak at approximately 3700 MW.

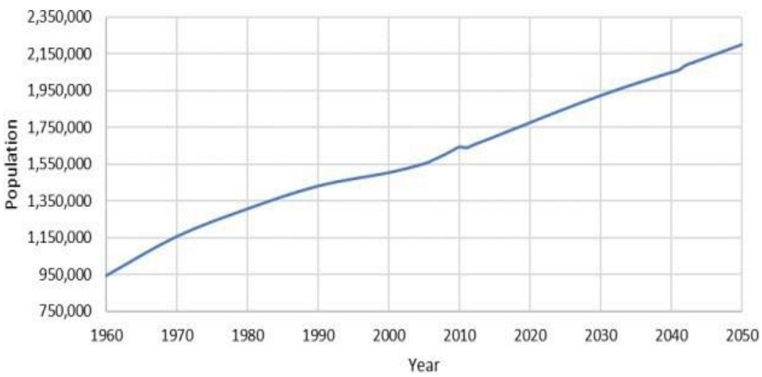

Figure 1. Prediction of South Australia’s population to 2050

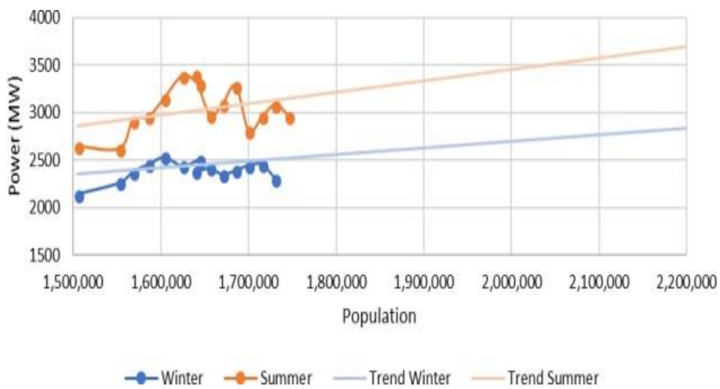

Figure 2. Prediction of maximum power demand against predicted population growth.

Energy demand variability caused by new technologies and increasing energy efficiencies are beyond the scope of this paper. EVs are the most significant of these new technologies, and one that the AEMO has noted as significant to future demand predictions.

The potential demand of EVs on South Australia's energy grid was projected by comparing to trends in EV uptake in the United States of America. The United States was chosen due to its geographic and spatial similarities in terms of population density and demographic characteristics.

Fig. 3 shows that over the 2014 – 2016 period there was an average increase of EV uptake of 48% per year. Historically, Australia tends to be slower in the uptake of new vehicle technologies, such as the withdrawal of leaded fuel (1995 in the USA compared to 2002 in Australia). Taking this into account, an EV uptake of 30% per year was used. This uptake percentage of EVs was then compared to South Australia's population and the current EV ownership. The current number of EVs registered in South Australia was divided by the population to determine the number of EV's per capita. This was then increased by 30% and multiplied by the projected population to estimate the number of EVs registered annually. This was compounded annually to determine the projected ownership of EVs in South Australia.

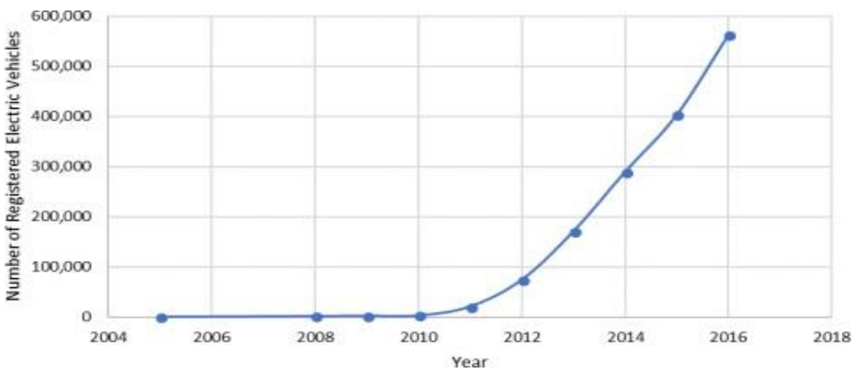

Figure 3. Electric Vehicle Registrations in the United States of America 2004- 2016

$$EV_{Tot} = Pop_{Present} \times EV_{pp} \tag{10}$$
$$EV_{pp} = EV_{pp\text{-}past} \times 130\% \tag{11}$$

EV_{Tot} represents the total number of EVs, EV_{pp} is the number of EV per capita. $EV_{pp\text{-}past}$ represents total EV per capita of the previous year. Fig. 4 outlines the predicted ownership of EVs in South Australia.

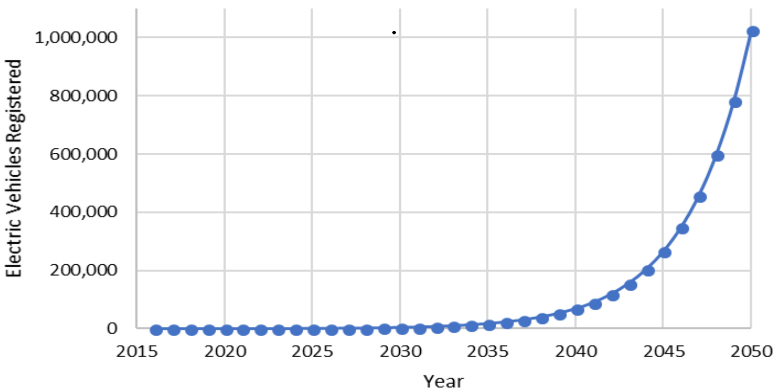

Figure 4. Predicted Electric Vehicle Registration in South Australia to 2050.

The average in-home charging station capacity for an EV is currently 0.01 MW, taking between 1 to 2 hours to charge an average EV. For this model, an assumption was made that 60% of all EVs would be charged at home, between the hours of 6 and 8 pm, when most people are home for the evening, consistent with current peak demand on the NEM. A maximum demand was calculated as follows:

$$EV_{dem} = \frac{\left(EV_{Tcharge} \times 60\%\right)}{2hr} \quad (12)$$

$$EV_{Tcharge} = EV_{Tot} \times Q_{Charge} \quad (13)$$

where EV_{dem} represents the energy demand from EVs, $EV_{Tcharge}$ represents the total power required to charge all registered EVs at one point in time and Q_{charge} represents the size in W of the home charging unit.

As can be seen in Fig. 5, the peak energy demand for EV charging will reach approximately 3100 MW by 2050. The remaining 30% of vehicles not charging could be plugged into the network and act as a power source in the Smart Grid, easing pressure on energy generators during these times of peak demand.

The total predicted demand on the energy network, including EVs can be seen in Fig. 6.

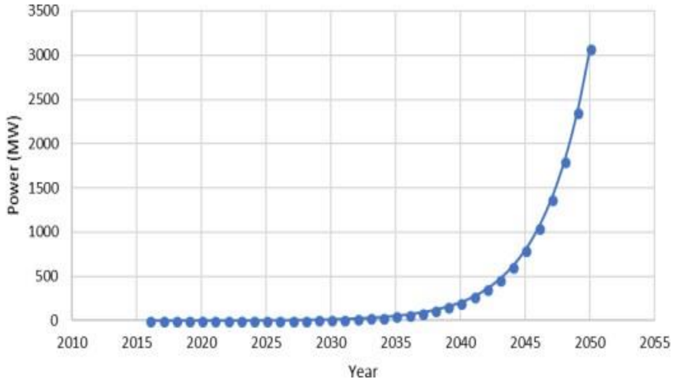

Figure 5. Estimated Peak Energy Demand for Electric Vehicle Charging.

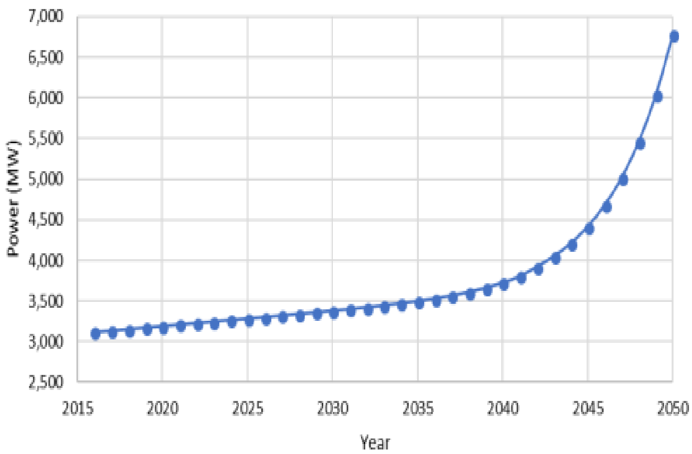

Figure 6. Combined Estimated Energy Demand from Population Growth and Electric Vehicle Uptake.

4.1. Three Scenarios for Future Energy Capacity in South Australia

According to the AEMO, in 2017 54.8% of energy generated in South Australia was from natural gas generation, 35.5% wind, 9.2% diesel and 0.1% large-scale solar, 0.4% biofuels. The role of small-scale rooftop solar PV was not insignificant, generating 1,016 GWh in 2016-17, however, this cannot be counted towards the RET.

To model South Australia's future energy mix, three scenarios were developed. General assumptions were made, as follows:

The average lifespan of energy generators in Australia was used as the decommissioning date for all generators. Furthermore, no coal generators would be commissioned in South Australia, and the commission costs in Table I were used. The aim for all models was to increase generation capacity to between 9,000 and 10,000 MW by 2050 to ensure sufficient energy supply. Any new renewable energy generators commissioned in these scenarios were based on a mix of 60% wind and 40% large-scale solar PV.

4.2. Scenario 1: 1:1 Generation Capacity Replacement

The model for scenario 1 was based on the assumption that all energy generators in South Australia would be decommissioned at the end of their expected lifespan. As each generator reaches the end of its lifespan, a gas generator is refurbished or replaced with a gas generator of the same capacity. All other generators at the end of their lifespan is replaced with a renewable energy generator of the same capacity. The aim of this scenario is to promote the use of renewable energy while retaining the security and cost- effectiveness of on- demand gas generators in the energy network. This appears to be a highly likely scenario for the state.

4.3. Scenario 2: 30% Generator Refurbishment Rate at the end of Technical Lifespan

This model assumes that 30% of all energy generators will be refurbished at the end of their life span and remain part of South Australia's energy network. The remaining 70% will be decommissioned at the end of their life span. Furthermore, to ensure adequate energy generation, every 3 years between 2025 and 2050 renewable energy generators with a capacity of 400MW will be commissioned. This scenario aims to balance the cost-effectiveness of refurbishment with a phase-out of the non-renewable energy generators

TABLE I. CAPITAL COSTS AND LIFESPAN OF ENERGY GENERATORS

Generator Type	***$/1 MW***	***Lifespan (years)***
Wind	2,400,000	25
Large-scale solar PV	2,190,000	20
CCGT	1,414,000	30
OCGT	1,400,000	30
Coal	3,076,000	35
Hydro	3,589,000	35
Battery storage	4,500,000	N/A[a]

[a] with modular battery design and regular cell replacements.

4.4. Scenario 3: 100% Renewable Energy Generation by 2050

Scenario 3 considers the potential for South Australia's energy generation to be entirely renewable by 2050. In this scenario, all energy generators are decommissioned at the end of their lifespan. Any non- renewable generator still within its technical lifespan in 2050 would be decommissioned. As in scenario 2, renewable energy generators with a capacity of 400 MW are commissioned every 3 years, with the addition of 500 MW to be commissioned in 2050 to replace the decommissioned non- renewable generators.

4.5. Economic Feasibility and Future Energy Mix

Using South Australia's AEMO Generation Information published in March 2018, and the average lifespan of energy generators in Australia, South Australia's probable energy mix in 2025 can be seen in Fig. 7.In 2025, not accounting for yet to be publicized commissioned or de-commissioned generators, South Australia's energy mix is likely to be 74% from renewable sources as can be seen in Fig. 8. Seen in Fig. 9, in Scenario 1, by 2050 the percentage of renewable energy generated in South Australia will rise to 84%. This is higher than the percentage share in Scenario 2, where renewables would account for 80% of energy generated (Fig. 10). Fig. 11 displays Scenario 3's 100% renewable energy generation. The estimated cost of each scenario was calculated based on the capital costs of commissioning the required generators in each model, and in the case of scenario 2, the average cost of refurbishing a gas generator (based on the average cost of refurbishing a coal generator) of \$0.0268 million per megawatt year.

The estimated cost of Scenario 1 based on the figures in Table I is \$9.4 billion. Scenario 2 would cost approximately \$7.9 billion. Scenario 3 would cost \$ 10.4 billion, making it the most expensive option. Costs are an estimate, as technological advances mean renewable technologies require less initial capital to develop and are more efficient in their generation of energy.

5. DISCUSSION AND CONCLUSION

It is clear that South Australia is well ahead of it is renewable energy goals, and making a significant impact on Australia's RET. By 2025 South Australia will have exceeded their goal of 50% of all energy generated from renewable sources. Rather, South Australia will have an energy generation mix where almost three-quarters of all energy generated is renewable.

The three scenarios for the potential energy mix of South Australia in 2050 offer some exciting implications for South Australia's future. For South Australia to rely solely on renewables for its energy demands is the costliest option, requiring higher capital costs to commission wind and solar generators. Not included in this prediction was the added cost of energy storage, a requirement to meet energy demand and reliable supply during adverse events.

Scenario 1 retains the security of gas energy generation for on-demand electricity while moving all other energy generation to low emission, renewable sources. However, the continued reliance on gas generators equals a continued dependence on fossil fuels.

Scenario 2 is the most cost-effective option of the three models. Refurbishment of energy generators to continue operations past their technical lifespan is common, however it is not always the best option. Scenario 2 focuses on removing non-renewable energy generators when they have reached the end of their lifespan in order to develop renewable options. However, as with scenario 3, energy storage solutions would have to be considered to maintain energy security.

It is important to note that South Australia is connected to the NEM, and as such any policy would need to consider the role of generators outside of the state, and South Australia's ability to feed into the network.

South Australia should consider developing renewable energy targets beyond 2025. As can be seen in this model, a target of 80% renewable energy generation is achievable by 2050, and 100% renewable energy in South Australia is possible by the concluding decades of the century.

From these results, the model can be adjusted to consider the potential future energy mix of the National Energy Market, and the feasibility of Australia's RET can be determined. In future work we intend to extend this model to other Australian states.

Project-based learning is not new to engineering education. Multiple competencies and skill elements such as problem solving and information literacy can be developed within the project. By choosing currently popular project-based research topics, student engagement can be maintained; moreover, they can be encouraged to make an immediate contribution to the area of specialisation. By assigning the same task to multiple students and giving them the choice of working on, for example, different geographical regions, it is possible to assess how the same set of research questions and research objectives are handled by different students. We described an example (case study) of the use of project-based approach to achieve both unit learning targets and Engineers Australia competency units and elements.

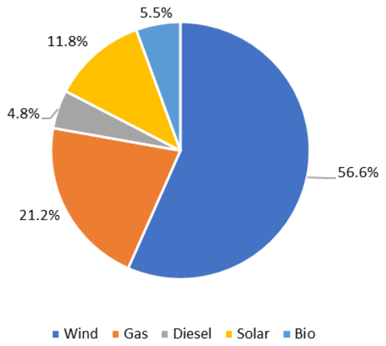

Figure 7. South Australia's Energy Mix, 2025

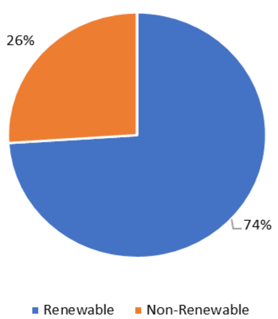

Figure 8. Percentage of Renewable Energy, South Australia, 2025

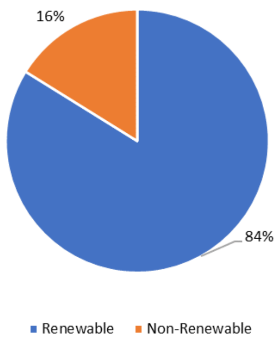

Figure 9. Percentage of Renewable Energy, Scenario 1, South Australia, 2050

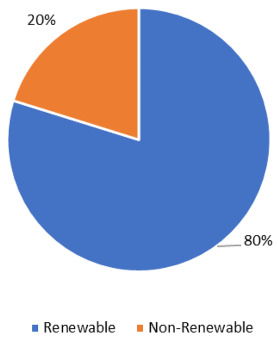

Figure 10. Percentage of Renewable Energy, Scenario 2, South Australia, 2050

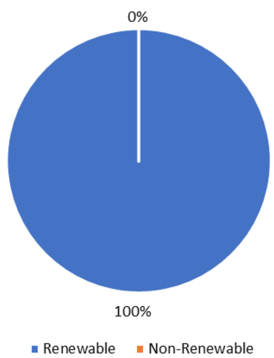

Figure 11. Percentage of Renewable Energy, Scenario 3, South Australia, 2050

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Regional Flood Estimation in Australia: Past, Present and Future

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Abstract

A major portion of Australia's population, infrastructure, and industry is located in flood-prone areas. Furthermore, in Australia, floods account for nearly 30 per cent of Australia's natural disasters. The series of floods that hit Queensland in the summer of 2010-11 killed 28 people, caused $2.3 billion in property damage, and reduced Australia's gross domestic product by an estimated $30 billion. These estimates, however, neglect the real costs associated with loss of personal possessions, shattered lives and battered communities. There is no doubt, it seems like damaging floods have been in the news daily over the last few years. In 2011 alone, the global flood damage was estimated to be worth $70 billion. While, engineers cannot stop floods from occurring, strategies should be put in place to reduce the risk of large economic losses, environmental damage, and loss of life. Development of economically efficient and floodplain management plans requires good estimates of the risk of flooding. In Australia, the risk computation is done following guidelines in Australian Rainfall and Runoff (ARR) Book 4 "A Guide to Flood Estimation", for which the latest update was published in 1987. That update included the Probabilistic Rational Method and various local methods for design flood estimation published over 30 years ago. ARR 1987 has served the nation for over 30 years and has also been guide for flood estimation for many other countries. Indeed, it is a remarkable document that has stood the test of time. But it must be recognised, given the long-standing problems associated with some of the methods in the document, recent advances that address those problems, and the current national interest in new design flood estimates, the time has arrived to update Book 4 to maintain the statistical credibility of the national guidelines and to provide accurate risk and uncertainty assessments.

Keywords: Floods, Engineering, Australia, Design Flood, Ungauged Catchments

1. INTRODUCTION

Accurate estimates of the magnitude and frequency of flood flows are needed for the design and operation of water-use and water control projects, for floodplain definition and management, and for the design of transportation infrastructure such as bridges and roads. Floods and flooding are not a new problem in Australia. In the late 1950s, it became apparent that uniform regional flood frequency methods were needed for national wide application, as well as to facilitate coordination among government agencies and members of the private sector who participate in the management of water resource systems that affect flood risks.

Design floods can be estimated based on recorded streamflow data using the most direct method of flood frequency analysis. Typically, the design flood estimation problem requires a sufficiently long period of streamflow data. Unfortunately, at many locations in Australia there is lack of reasonable quality recorded streamflow data. For example, as at 1993, of the 12 drainage divisions in Australia, seven did not have a stream with 20 or more years of data (Vogel et al., 1993). For catchments with no streamflow data (i.e. ungauged catchments), a regional flood estimation method is generally adopted to estimate design floods, which attempts to transfer flood characteristics information from gauged catchments to the ungauged one. Estimation of design floods on small to medium sized ungauged catchments is probably the most common design problem in Australian flood estimation (Pilgrim, 1987). The average amount spent on these projects per year was estimated at approximately $250 million as at 1985 (Flavell, 1985; Pilgrim, 1986); this is equivalent to over $750 million per annum in 2017 (based on long term CPI series for Australian capital cities).

Australian Rainfall and Runoff (ARR) 1987 recommended various regional flood estimation methods for small to medium sized ungauged catchments for different regions of Australia (I.E. Aust., 1987). Since 1987, the regional flood methods in ARR have not been upgraded although there have been an additional 25 years of streamflow data available and notable developments in both at-site and regional flood frequency analyses procedures. As a part of the current revision of the ARR (4th Edition), Project 5 Regional Flood Methods for Australia focused on the development, testing and recommendation of new regional flood estimation methods for Australia by incorporating the latest data, statistical techniques and the development of an easy to use software application.

Hence, the purpose of this paper is three-fold, firstly we present an overview of previously adopted regional flood methods in Australia, we then discuss the scope and status of the research in relation to the upgrade of the ARR and finally we provide some useful information and insights on future directions in regional flood estimation.

2. REGIONAL FLOOD ESTIMATION METHODS IN ARR 1987 AND SIGNIFICANT ADVANCES IN RESEARCH POST ARR 1987

Regional flood estimation methods recommended in ARR1987 for the various states of Australia are tabulated and summarised in Table 1. Some important aspects are noted below

(i) Separate methods or maps of runoff coefficients were recommended for different states. The state boundaries do not carry any hydrological significance and are often criticized in the literature. Furthermore, state boundaries prohibit the pooling of data from adjacent states, hence ARR 1987 did not consider data pooling.

(ii) Allot of the regions/states used regional flood methods based on small sample sizes (many gauging stations with 10 years or less of data) which may result in regional estimation lacking in statistical and hydrological significance with allot of uncertainty and bias.

(iii) The index flood method is based on the assumption of homogeneous regions, but the regions where index flood method was applied were not tested for regional homogeneity.

(iv) There was a lack of independent testing of the methods and uncertainty in final flood estimate is not well established.

There have been numerous developments in regional and atsite flood frequency analyses (R/FFA) and the statistical methods used for this analysis since the publication of ARR in 1987. Kuczera (1999) developed a Bayesian method of FFA, which has been incorporated in software called FLIKE (Kuczera and Franks, 2005). This can also account for the effects of errors due to rating curve extrapolation and can use regional estimates of floods to improve atsite FFA at sites with little or no data. Hosking and Wallis (1993) presented L moments based at-site and regional flood frequency analyses, which are less sensitive to record length and outliers in the data as with the method of moments procedure. To avoid boundary problem issues, Burn (1990) pioneered the region of influence (ROI) approach, which forms a region for each individual station on the basis of similarity in geographical or catchment attribute space. Haddad and Rahman (2012) used an enhanced ROI based on the minimization of the model error variance (MEV). Tasker and Stedinger (1989) presented an operational generalized least squares (GLS) regression approach which can account for inter-station correlation and variation in record lengths from site to site in developing regression based flood prediction equations. Reis et al. (2005) went on to further enhance the GLS method by introducing a Bayesian estimator of the MEV which can reduce uncertainty in a hydrological statistic of interest which ultimately leads to more accurate flood estimates. There have also been a number of studies (Srinivas and Rao, 2006 and Smith et al. 2015) that have also looked at different clustering methods based on flood data and catchment data similarities, which can lead to enhanced prediction ability of regional flood methods. Furthermore, there has been a recent interest on the application of non-linear methods in RFFA (Chebana et al., 2014, Durocher et al. 2015, Rahman et al. 2018 and Ouarda et al. 2018). These studied showed the superior performance of nonlinear methods over linear ones at that in particular, nonlinear methods allow for a more realistic understanding of the complexity of the flood generation process and true relationship between the dependent and predictor variables. What often goes neglected in regional flood estimation is the independent testing and validation of the method. Haddad et al. (2013) presented an in-depth analysis that looks at the validation regional hydrologic regression models using a Leave One Out and Monte Carlo cross validation procedures.

Table 1 Various regional flood estimation methods in ARR 1987

State	**Method**	**Database Used for Method**	**Important Points / Aspects**
New South Wales – Split into East & West	Probabilistic Rational Method & Index Flood Method	376 gauged catchments used. Minimum of 10 years data	Applicable to a certain area size. Considerable sampling uncertainty. No independent testing
Victoria	Probabilistic Rational Method	325 gauged catchments used. Minimum of 10 years data	Considerable sampling uncertainty. No independent testing
Australian Capital Territory	Multiple Regression Methods	14 gauged catchments used. Minimum of 10 years data	Considerable sampling uncertainty. No independent testing
Queensland	Various local methods – Main Roads Department	Based on very limited observed data	Arbitrary procedures. Lower accuracy than other states. No independent testing
South Australia	Various local methods	Based on limited observed data	Highly uncertain estimation. No independent testing
Western Australia	Rational Method & Index Flood Method	Based on limited observed data	Highly uncertain estimation. No independent testing
Tasmania – Split into East & West	Regional and Rational Methods	Based on limited observed data	Highly uncertain estimation. No independent testing
Northern Territory	Various Rational Methods	Based on limited observed data	Subject to large uncertainties depending on region.

3. THE PRESENT – DATABASE ADOPTED FOR NEW REGIONAL FLOOD FREQUENCY ESTIMATION (RFFE) METHOD

Recorded streamflow data along with a set of climatic and catchment indices data is the backbone of any derived RFFE method. Collating a database of good quality for a RFFE is a considerable challenge. The challenge lies in maximising the amount of useful flood information, while minimizing the random error component as much as possible that is most often present in hydrological flood data. Six criteria were adopted in selecting stations for inclusion in the RFFE model.

(i) The catchment should not be greater than 1,000 km^2.

(ii) The record length of the annual maximum flood series for the finally selected stations should be at least 25 years.

(iii) The catchments should not have major regulation by storages.

(iv) A catchment should have less than 10% urbanisation.

(v) There should not be any major and use changes during the period of streamflow records being considered.
(vi) The quality of flood data should be rated acceptable by the gauging authority.

A detailed description of the data preparation procedure can be found in ARR Project 5 Stage 1, Stage 2 and Stage 3 reports (Rahman et al, 2009, 2012a and 2015), Haddad et al. (2010) and Ishak et al. (2013).

A total of 798 catchments were selected from the data-rich areas and 55 catchments from arid areas i.e. a total of 853 catchments from all over Australia. A summary of these 853 selected catchments from data-rich and arid areas is provided in Table 2. The geographical distribution of the selected 853 catchments is shown in **Figure 1**.

Table 2 Summary of the selected 853 catchments (data-rich and arid areas) State No. of stations

State	No. of stations	Streamflow record length (years) (range and median)	Catchment size (km^2) (range and median)
New South Wales & Australian Capital Territory	176	20 – 82 (34)	1 – 1036 (204)
Victoria	186	20 – 60 (38)	3 – 997 (209)
South Australia	28	20 – 63 (37)	0.6 – 708 (62.6)
Tasmania	51	19 – 74 (28)	1.3 – 1900 (158.1)
Queensland	196	20 – 102 (42)	7 - 963 (227)
Western Australia	111	20 – 60 (30)	0.5 – 1049.8 (49.2)
Northern Territory	50	19 – 57 (42)	1.4 - 4325 (352)
Sub Total	**798**	**19 – 102 (37)**	**0.5 – 4325 (178.5)**
Arid Regions	55	10 – 46 (27)	0.1 - 5975 (259)
TOTAL	**853**	10 – 102 (36)	0.1 – 5975 (181)

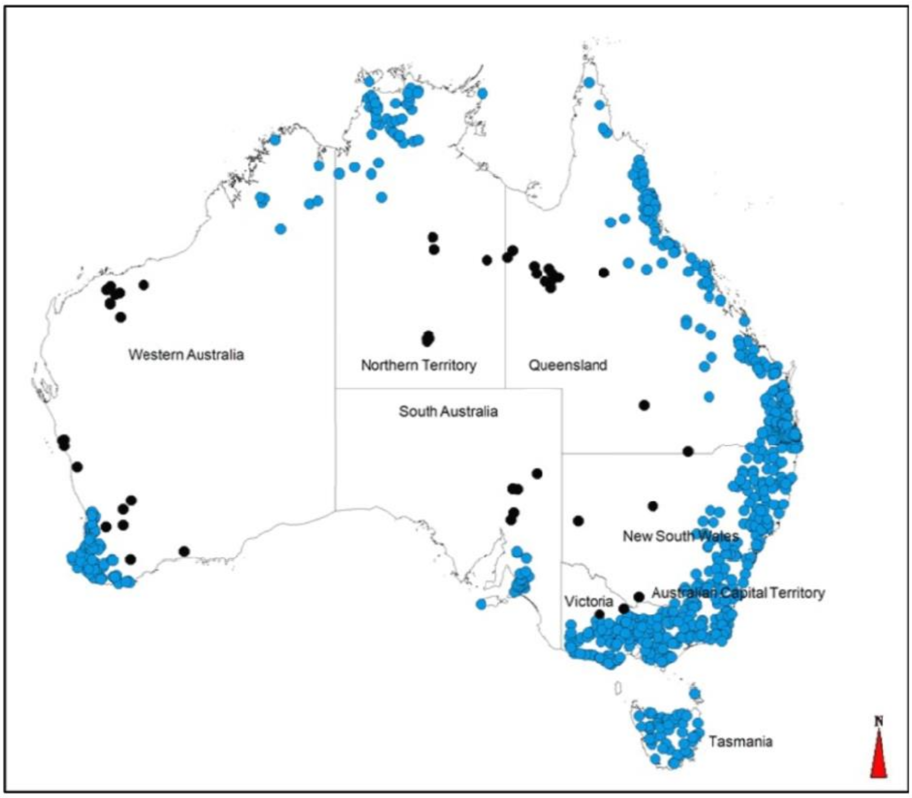

Figure 1 Geographical distribution of the selected 853 catchments (data-rich and arid areas) – adapted from Project 5, Stage 3 report

A total of nine predictor variables were used in the development and testing of the RFFE Technique 2015, as outlined below:

i. catchment area in km^2 (area);
ii. mean annual rainfall at catchment centroid in mm (rain);
iii. design rainfall intensity at catchment centroid (in mm/h) for 6-hour duration and AEP of 50% ($_{I6,50}$);
iv. design rainfall intensity at catchment centroid (in mm/h) for 6-hour duration and AEP of 2% ($I_{6,2}$);
v. v. a ratio of design rainfall intensities of $I_{6,2}$ and $I_{6,50}$ ($I_{6,2}/I_{6,50}$)
vi. design rainfall intensity at catchment centroid (in mm/h) for duration equal to t_c hours and AEP of 50% ($I_{tc,50}$);
vii. design rainfall intensity at catchment centroid (in mm/h) for duration equal to t_c hours and AEP of 2% ($I_{tc,2}$);
viii. a ratio of design rainfall intensities of $I_{tc,2}$ and $I_{tc,50}$ ($I_{tc,2}/I_{tc,50}$); and
ix. shape factor, which is defined as the shortest distance between catchment outlet and centroid divided by the square root of catchment area.

4. AT-SITE FLOOD FREQUENCY ANALYSIS

For at-site flood frequency analysis, the LP3 distribution was fitted with the Bayesian parameter estimation procedure using the FLIKE software (Kuczera, 1999). The potentially influential low flows (PILFs) were identified using the multiple Grubbs-Beck test (Lamontagne et al., 2013; Cohn et al., 2013) and were censored in the flood frequency analysis. The standard deviation (SD) and skew of the $\log_e$ (Q) series (where Q represents the AM flood series) were estimated after necessary censoring of PILFs from the respective AM flood series. For each of the 798 stations selected from the data-rich areas, flood quantiles were estimated for AEPs of 50%, 20%, 10%, 5%, 2% and 1%. For the data-poor (arid) areas, the flood quantiles were estimated for AEPs of 50%, 20%, 10%, 5%, 2% and 1% at each of the 55 stations based on the abstracted partial duration series data (considering average number of events per year = 0.5) by fitting a Generalised Pareto distribution using L moments

5. REGIONAL FLOOD FREQUENCY ANALYSIS

A number of RFFE models were developed and tested using the national database of 798 stations in the data rich regions. These include the Probabilistic Rational Method (PRM) (IE Aust., 1987) and various regression based techniques: Quantile Regression Technique (QRT) based on Ordinary Least Squares (QRT-OLS) and Generalised Least Squares (QRT GLS) (Tasker and Stedinger, 1989; Reis et al, 2005), and Parameter Regression Technique (PRT) based on GLS regression (PRT-GLS). In the PRT, prediction equations were developed for the three parameters (i.e. mean, standard deviation and skewness or frequency factor) of the log-transformed annual maximum flood series to estimate flood quantiles from a regional LP3 distribution. It was found that the QRT and PRT methods performed very similarly for various Australian states (Haddad, Rahman and Stedinger, 2012). However, the PRT method offered several practical advantages over the QRT: (i) PRT flood quantiles increase smoothly with decreasing AEPs; (ii) flood quantiles of any ARI (in the range of AEPs of 50% to 1%) can be estimated from the regional LP3 distribution; and (iii) it is straightforward to combine any at-site flood information with regional estimates using the approach described by Micevski and Kuczera (2009) to produce more accurate quantile estimates. For these reasons, the PRT coupled with Bayesian GLS regression was finally adopted for general application to Australia in the data-rich region.

One of the apparent limitations of the ROI approach is that for each of the gauged sites in the region, the regional prediction equation has a different set of model parameters; hence a single regional prediction equation cannot be pre-specified. To overcome this problem, the parameters of the regional prediction model for all the gauged catchment locations in a ROI region have been pre-estimated and integrated with an application tool. In the application tool, for a given location of the ungauged catchment, the parameter set of the nearest ROI sub-region is automatically selected for flood quantile estimation. The application of ROI and PRT methods was deemed inappropriate in the arid areas as ROI approach requires a number of gauging stations to form sub-regions and the number of gauging stations in the arid areas of Australia is insufficient for this purpose. Hence a simpler RFFE method was considered more appropriate for the arid areas. Here, an index type approach as suggested by Farquharson et al. (1992) and tested by Zaman, Rahman and Haddad (2012) was adopted. The 10% AEP flood quantile (Q10) was used as the index variable and a dimensionless growth factor (GF) for AEP of x% (GF_x) was used to estimate Q_x

To assess the performance of the developed RFFE techniques, a leave-one-out (LOO) validation approach was applied where one catchment was left out and a model was developed using the remaining catchments and then the developed model was tested on the single catchment that was left out. The procedure was repeated until all the catchments were tested once. This ensures an independent testing of the RFFE technique for each of the catchments in the database. For both the data-rich and data-poor regions, the LOO validation approach was adopted. Further information on the LOO validation approach can be found in Haddad et al. (2013). Uncertainty was looked at and assessed as part of the analysis.

In developing the confidence limits for the estimated flood quantiles, a Monte Carlo simulation approach was adopted by assuming that the uncertainty in the first three parameters of the LP3 distribution (i.e. the mean, standard deviation and skewness of the logarithms of the annual maximum flood series) can be specified by a multivariate normal distribution. Here the correlations among the three parameters for a given region were estimated from the residuals of the GLS regression models of the LP3 parameters. The mean of the LP3 parameter was given by its regional predicted value and the standard deviation of the LP3 parameter was the square root of the average variance of prediction of the parameter at the nearest gauged site. Based on 10,000 simulated values of the LP3 parameters from the multivariate normal distribution as defined above, 10,000 Q_x values were estimated, which were then used to develop the 90% confidence intervals.

In the adopted RFFE technique, Australia was finally divided into seven regions. There are five data-rich regions, as shown Table 3. For each of these data-rich regions, the ROI approach was implemented e.g. for data-rich Region 2, ROI was implemented using 51 stations from Tasmania. All the 558 stations from Victoria (VIC), the Australian Capital Territory (ACT), New South Wales (NSW) and Queensland (QLD) form Region 1. A total of 28 stations from South Australia (SA) form Region 3. Fifty stations from the Northern Territory (NT) and 8 stations from the Kimberley region of Western Australia (WA) i.e. a total of 58 stations are combined to form Region 4. A total of 103 stations from south-west Western Australia (WA) form Region 5. The formation of regions in the arid areas in Australia is a difficult task, as there are only 55 catchments available from a vast area of Australia. There are two alternatives: (i) formation of one region with all the 55 stations; and (ii) formation of smaller sub-regions based on geographical proximity, noting that too small a region makes the developed RFFE technique of little statistical significance. Examination of a number of alternative sub-regions led to the formation of two regions from the 55 arid catchments: Region 6 (11 catchments from the Pilbara area of WA) and Region 7 (44 catchments from all other arid areas except the Pilbara.

Table 3 Summary Details of five data-rich regions and two data-poor/arid regions in RFFE Technique 2015

Region	Method to Form Region	No. of Stations	Estimation Model
Region 1: VIC + NSW + ACT + QLD	ROI	558	Bayesian PRT GLS
Region 2: Tasmania	ROI	51	Bayesian PRT GLS
Region 3: South Australia	ROI	28	Bayesian PRT GLS
Region 4: NT + Kimberley WA	ROI	58	Bayesian PRT GLS
Region 5: SW Western Australia	ROI	103	Bayesian PRT GLS
Region 6: Pilbara arid area	Fixed	11	Index flood method with Q_{10} as the index variable
Region 7: All other arid area	Fixed	44	Index flood method with Q_{10} as the index variable

6. THE FUTURE – APPLICATION TOOL

The coefficients of the developed regression equations (for the five data-rich regions at each of the 798 gauged catchment locations and for the two arid regions) are embedded in a computer-based application tool (called RFFE Model 2015). The user is required to enter simple data input like latitude, longitude, catchment area and design rainfall intensity for the ungauged catchment (See Figure 2) of interest to generate the design flood estimates and 90% confidence limits for AEPs of 50%, 20%, 10%, 5%, 2% and 1%. It also provides a set of the nearest gauged catchments (which have been used in developing the RFFE Model 2015) so that the user can compare the characteristics of the ungauged catchment of interest with the nearest gauged catchments of the model data set. The chapter on regional flood frequency estimation in Australian Rainfall and Runoff (4th edition) provides further information on the application tool with worked examples.

There are number of ongoing updates to be implemented, as noted below.

(i) At present, the regional flood estimation model with the ARR RFFE 2015 method has been based on annual maximum flow data up to 2013.

(ii) Large Flood Estimation Model to estimate floods lower than the 1% AEP should be incorporated into RFFE. This will make RFFE a comprehensive tool for regional flood estimation for a range of flood categories.

(iii) Nonlinear methods of flood estimation should be investigated as a viable alternative to linear methods future use.

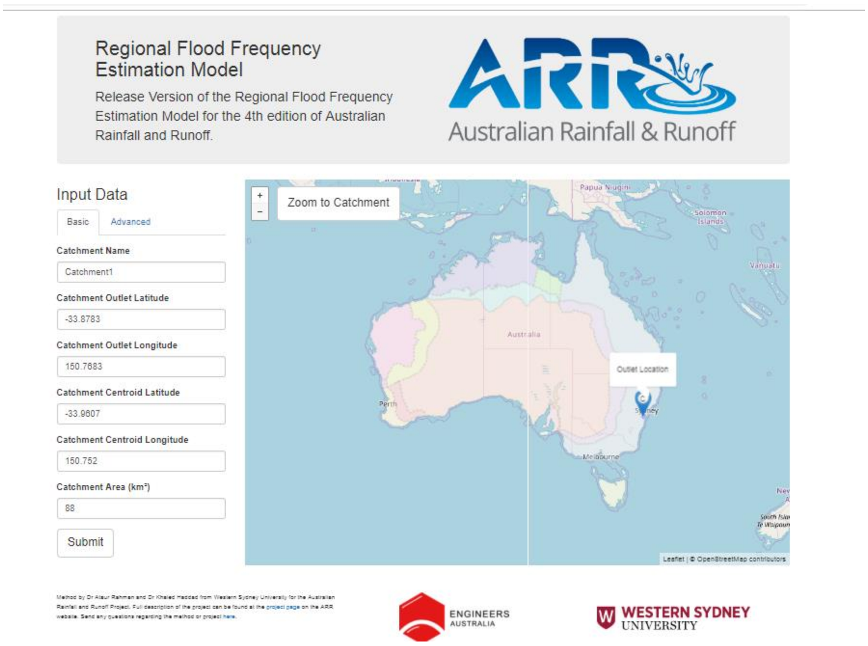

Figure 2 Windows interface of ARR RFFE 2015 Model

7. CONCLUSION

Australian Rainfall and Runoff (ARR) is indeed an excellent document which has served the Australian community for many decades while also being a valuable guide to other countries as well. However, the time has come for this document to be revised so that it maintains the statistical credibility going into the future and to provide accurate risk and uncertainty assessments. This paper gave a brief overview of the past, present and future directions of regional flood frequency estimation in Australia. It was shown that past methods lacked in many ways from both a hydrological and statistical point of view. To overcome this, a national comprehensive data base has been collated and the most up to date statistical methodology has been used to provide reasonably accurate flood estimation in ungauged catchments. To facilitate the easy use of the new methodology a computer-based application has also been developed. This makes the application of regional flood estimation uniform for all of Australia, while also providing many useful statistics, graphs and outputs that makes the interpretation of the estimates a lot cleaner.

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Laboratory Development for Electrical Engineering Program

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Abstract

Western Sydney University (WSU) is facing the challenge to accommodate more students and improve the quality of teaching facilities. Being a relatively new university in Sydney, Western Sydney is in a positive competition with well-established universities in the area of Electrical Power Engineering. It makes the question of updating and improving the laboratories is a real challenge. WSU has upgraded their laboratories with state of art equipment and systems. The new laboratories can coder many subjects ranging from Electronics, Power and Machines, Power Systems, Renewable Energy and Smart Grids. This paper outlines the recent laboratories development.

Keywords: Honours, thesis, WSU, final year project, engineering course, learning

1. INTRODUCTION

The engineering profession is about manipulation of materials, energy, and information, thereby creating benefit for humankind. Engineers must have a knowledge of nature that goes beyond mere theory—knowledge that is traditionally gained in educational laboratories to do this successfully, [1-3]. Developed countries now face the challenge of modernizing an aging electricity grid infrastructure in a field where the workforce is rapidly aging. Green, smart-power energy programs that support growth while respecting the environment are on many government agendas [4]. It is very important to establish an advanced power engineering laboratory, including the latest technology in transformers, electrical machines, drives and power electronics. The target was a laboratory where students can use the machines connected to the computer screen and they can get the experimental results on their USB or being sent to their email addresses.

At Western Sydney University, the idea is to show students electrical motors and drives working at realistic real life voltages (240V, 50Hz) with a rated power in the range of few kWatts.

2. LABORATORY DEVELOPMENT

After consultation and deliberations and investigating various options, it was agreed and decided to purchase Lab Volt equipment at Western Sydney University in 2016. The program starts with a variety of courses providing in-depth coverage of basic topics related to the field of electrical energy such as ac and dc power circuits, power transformers, rotating machines, ac power transmission lines, power electronics, power systems and renewable energy systems.

The first stage laboratory is dedicated to teaching basic electrical circuits: The primary utilization of this laboratory is for teaching most of the sections of Electric circuits and electronics. The laboratory has multiple student experiment stations, each equipped with basic instruments required to perform experiments and carry out measurements related to fundamental principles of electrical circuits. Laboratory equipment include breadboards, multi-meters, power supplies, and other teaching tools, e. g Electrical Fundamentals students conduct experiments and perform measurements demonstrating basic principles of circuit theory, including Ohm's law, Kirchhoff's laws of current and voltage, superposition, Thevenin and Norton models, etc., while students conduct experiments and perform measurements involving diode and transistor circuits in electronics. [5-6]. The program then builds on the knowledge gained by the student through these basic courses to provide training in more advanced subjects such as transformers, electrical machines and drives, power electronics, power systems and renewable energy systems.

Lab Volt combines a modular design approach with computer-based data acquisition and control to provide latest training in Power engineering systems. It is oriented toward today's competence requirements, including electricity fundamentals (i.e., dc power circuits), single-phase and three-phase ac power circuits, power transformers, three-phase transformer banks, permanent magnet dc motors, three-phase rotating machines (induction machine and synchronous machine), and power factor correction. The system features the Four-Quadrant Dynamometer/Power Supply, and the Data Acquisition and Control Interface, two state-of-the-art USB peripherals that greatly enhance the learning experience of students. The courseware in the LabVolt provides students with a sound knowledge of basic electric power technology. Two other rotating machine courses from the Electric Power Technology Training Program can be optionally added to the LabVolt. These courses complete student training in rotating machinery by adding knowledge of the following conventional rotating machines: separately excited, shunt, series, and compound dc motors, separately excited, shunt, and compound dc generators, universal motor and single-phase induction motor (capacitor-start and split-phase types). These machines, although still in use today, are less common in modern applications.

*The training system teaches the principles of three-phase rotating machines. To this end, students follow a complete curriculum that includes these topics:

- More advanced courses that cover different concepts and devices important to the study of three-phase rotating machines, such as single-phase and three-phase ac power circuits, single-phase and three-phase power transformers, and power factor correction.
- Courses that cover the operation of different rotating machines, such as permanent-magnet dc motors, induction machines, and synchronous machines.
- Optional courses that cover less common machines, such as conventional dc machines, universal motors, and single-phase induction motors.
- The course curriculum of the Electric Power Technology Training Program is highly flexible and allows a multitude of different customized training solutions.
- The courseware includes student manuals and instructor guides with all the theory required to perform the hands-on experiments.
- All workstations, modules, and components are very sturdy to ensure a prolonged service life in a demanding environment such as a training laboratory.
- The modular design approach of the training equipment allows a large variety of courses to be performed using a small number of modules, without unnecessary duplication of equipment.
- All electrical components can be interconnected without electric shock hazard since all live parts of the connection leads are concealed and insulated.
- All electrical symbols representing the components used in a laboratory exercise are clearly silk-screened on the front panel of the modules.
- The training system includes two highly versatile USB peripherals:

Four-Quadrant Dynamometer/Power Supply, Model 8960-2. This module is used as a dc and ac power source. It can also be mechanically coupled to all rotating machines to operate as a prime mover or brake. Data Acquisition and Control Interface, Model 9063. This module gives access to a large variety of computer-based measuring instruments via the LVDAC-EMS software. Figure 1 shows a working station for different laboratories and an IGBT Chopper/inverter to be used when it is needed.

Figure 1: A Lavoltas workstation at the WSU electrical engineering lab.

2. TOPICS COVERAGE

1) Electric circuits: Ohm's Law, Equivalent Resistance, Power in DC Circuits' Series and Parallel Circuits; Solving Simple AC Circuits using Circuit Impedance Calculation, Inductive and Capacitive Reactance

2) Electrical Machines and drives: Permanent Magnet DC Motor and Generator; Transformer Winding Polarity and Interconnection; Transformer Losses, Efficiency, and Regulation; The Three-Phase Squirrel Cage Induction Motor, The Three-Phase Synchronous Motor and Generator

3) Power Electronics: The training system also includes three highly versatile power electronics modules controlled using the Data Acquisition and Control Interface:

   - IGBT Chopper/Inverter. This module is used to implement various types of choppers and inverters.
   - Power Thyristors. This module is used to implement various thyristor-based devices (e.g., bridges, ac power controllers, solid-state relays)
   - Rectifier and Filtering Capacitors. This module is used to implement various types of power diode rectifiers.

4) Renewable Energy System: it provides in-depth coverage of basic renewable energy systems.
   - An introduction to dc power circuits,
   - The principles behind the production of electrical energy from both solar power and wind power.
   - The storage of electrical energy produced from renewable resources into lead-acid batteries for future consumption.

5) Power Systems: LabVolt provides training in more advanced subjects such as:
   - Home energy production from renewable resources (wind and sunlight),
   - Large-scale electricity production from hydropower,
   - Large-scale electricity production from wind power (doubly-fed induction generator [DFIG], synchronous generator, and asynchronous generator technologies),
   - Smart-grid technologies including high voltage DC transmission and storage of electrical energy in batteries.

2.1 MAJOR TECHNOLOGIES THAT INCLUDED IN THE LABORATORY

- Accurate Measurement and Control – One primary characteristic of a smart grid is the presence of digital technology to facilitate remote measurement, communication, and control of power system components.
- Power Electronic Converters – The presence of power electronics in transmission and distribution systems has grown drastically, primarily due to reduced cost.
- Renewable Power Generation – Generation of electricity from renewable energy sources is one of today's most relevant engineering topics.
- Grid-Connected Energy Storage – The utilization of bulk energy storage in electric power systems is limited, predominantly because of high cost. However, this technology has the greatest potential to revolutionize how electricity is generated, transmitted, and consumed.

2.2 DESIGN PRINCIPLES

The success of the project relied on the following design principles:

1) Safety, students will get the results on the screen on their laptop and therefore, the system is very safe for students and for laboratory demonstrators. The 3AC Power Supply and Safety Unit consist of a fixed-voltage three-phase ac power source enclosed in a module. The 3AC Power Supply and Safety Unit comprise single-phase and three-phase ac power outlets with overcurrent protection and type B residual current protection. It also includes the following features for additional safety: lockable power-on switch, emergency stop button, under-voltage release, and single-phase, earthed and polarized ac power outlets. It can be used to power the 3AC 400V/DC 230V/Power Supply using the color-coded safety banana jacks.

2) Robust and versatile: The laboratories of undergraduate institutions must be facilitating the study of introductory as well as advanced topics, and be easy enough to be operated by laboratory demonstrators or postgraduate students.

3) Cost/Space efficient: University campuses being in Sydney and Parramatta city centres with space limitations; the laboratories must be flexible to be used.

3. CONCLUSION

LabVolt is a new power engineering laboratory at Western Sydney University. It is an advanced power engineering laboratory, including the latest technology in transformers, electrical machines, electrical drives and power electronics. This laboratory presents the new generation of laboratories where the results of the experiments are presented in the digital and graphic formats.

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Challenges in Teaching Geotechnical Engineering at Western Sydney University (WSU)

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Abstract

WSU has been teaching geotechnical engineering, a sub-specialisation of the civil engineering degree since 1994. It has faced many challenges as the student cohort in civil engineering grew from a handful to about a thousand students today. The challenges in teaching geotechnical engineering stems from a variety of sources: the inherent difficulty of the subject matter, the profile of students at WSU, new and emerging technologies, multi-campus setup and relating to industry needs. Most are not necessarily unique to WSU, but they impact on WSU to a greater extent than most. This paper discusses the authors' take on these issues.

Keywords: Geotechnical engineering, WSU, civil engineering, soil mechanics

1. INTRODUCTION

Geotechnical engineering is a sub-specialisation of civil engineering, of which the degree courses are currently in demand in Australia. This is a reflection of the high demand for the civil engineering professions in recent years. In its June 2018 publication, Engineers Australia reported that the engineering occupation which recorded the most vacancies has consistently been civil engineering. As of June 2018 there were almost 2,300 vacancies for this occupation, and the majority of these were in the major states of New South Wales (where WSU is based), Victoria and Queensland. Demand for civil engineers would normally translate to corresponding need for geotechnical engineers. This is borne out by the information released by Australia Visa Bureau revealing that the profession of "geotechnical engineer" as defined by the Australian and New Zealand Standard Classification of Occupations (ANZSCO) 2332-12 is currently in demand by employers in Australia.

Civil engineering occupations in Australia have been fuelled in the last few years by large infrastructure spending and the property boom. With the population of Australia projected to hit 36 million by 2050 and up from the current level of 24.8 million as of November 2018, there will be continuing need for housing, schools, hospitals, roads and other infrastructures. The need for civil engineers to not only maintain the existing infrastructures, but also build new ones to sustain a growing population over the next 20 years is a compelling one. As one of 8 universities offering on-campus civil engineering degrees in NSW, WSU has a special role in delivering a rigorous program to train civil and geotechnical engineers to meet the future needs of this country. This is especially so because WSU is located in Western Sydney, one of the fastest growing region in Australia where several infrastructure projects are in the pipeline (Infrastructure Australia n.d., accessed 30th Nov 2018 <https://infrastructureaustralia.gov.au>).

2. CIVIL ENGINEERING AND GEOTECHNICAL ENGINEERING AT WSU

Civil engineering started at WSU (previously the University of Western Sydney, Nepean) in 1994 with only a handful of students. By 2018 the cohort has grown substantially to about 1000 students. Of these about 800 are undergraduate and 200 are postgraduate coursework students. Another 130 students are currently engaged in postgraduate research degrees. Geotechnical engineering is a sub-specialisation of the 4-year civil engineering undergraduate degree which also offers sub-majors in structures, and water and environment. Two and a half core geotechnical units are also embedded in the civil engineering program, these are the 2nd-year Soil Mechanics, Pavement Materials and Design (0.5), and the 3rd-year Engineering Geomechanics units. Students who opt for the geotechnical sub-specialisation are required to complete four 3rd-/4th-year geotechnical electives: Pile Foundation, Highway Infrastructures, Hydrogeology and Waste Management.

The Master of Engineer (Civil) at WSU is a two-year full time postgraduate program accredited by Engineers Australia. The geotechnical specialised electives offered in the program includes Advanced Geotechnical engineering, Deep Foundations and Advanced Highway Infrastructures. The Master program is intended to provide a rounded as well as in-depth specialised engineering training for both domestic and international engineering students at a level more superior than an undergraduate level of study. This program also enables students with undergraduate civil engineering degrees from overseas not recognised in Australia to gain recognition for their studies and direct membership to Engineers Australia.

In developing the undergraduate and postgraduate coursework engineering programs, the diverse strengths of WSU engineering academic staff have been tapped to deliver a rounded learning experience and specialisation training for students. In general, these courses are designed to fulfil these main objectives:

a) align with requirements of Australian Quality Framework (AQF) and UWS Graduate attributes
b) satisfy Engineers Australia Stage 1 Competency standard for Professional Engineer
c) provide relevant sub-specialisation training (e.g. in geotechnical engineering) as a springboard for students to enter sub-specialisation engineering careers in Australia

Item (c), in particular, reflects the goal of WSU to produce civil engineering graduates as far as possible who are “industry ready”.

3. PROFILE OF WSU STUDENT COHORT

WSU is located in the growing Western Sydney region where 78 percent of our students come from. It has the largest number of students from lower socio-economic backgrounds of any university in Australia, with a significant proportion from non-English speaking backgrounds representing 170 nationalities (Widening Participation Annual Report 2017). WSU has a mission to widen participation among the low socio-economic status groups, namely the Aboriginal and Torres Trait islanders, students from out of home care, care leavers and young carers, student from Pacific Islander backgrounds women studying in non-traditional areas (e.g. engineering, more so geotechnical engineering), students from non-English speaking background and students from a refugee background. As such the civil engineering cohort reflects a strong mix of representation from the above low socio-economic status groups. All things considered, there is a proportion of WSU civil engineering students who are:

a) without a high level of English language and having some difficulty writing a structured report
b) lacking higher level high school mathematics and physics conducive for learning geotechnical engineering
c) unfamiliar with common software such as Word or Excel due to lack of opportunities prior to entering WSU

d) the first in the family to attend university which is a source of great pride for the family, but also a sombre reflection they are unlikely to receive wise counsel from a family member on managing their university studies
e) having no knowledge of soil mechanics before entering university, since the subject matter is not typically covered at high school

These issues are not necessarily unique to WSU, but they help shape the approach to teaching civil engineering in general, and more specifically geotechnical engineering at WSU.

4. APPROACH AND CHALLENGES WITH TEACHING OF GEOTECHNICAL ENGINEERING AT WSU

Geotechnical engineering is embedded within the civil engineering course curriculum at WSU, so the teaching strategy for geotechnical engineering is guided by the overall strategy adopted for the civil engineering degree. The progression of the undergraduate geotechnical engineering teaching is shown in Figure 1 below.

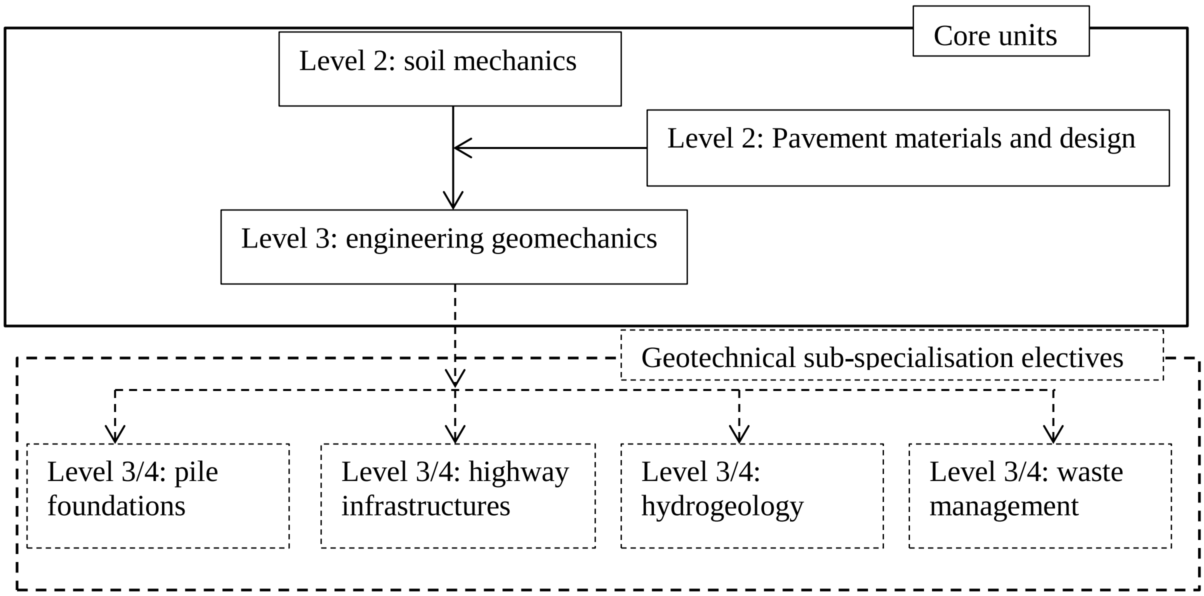

Figure 1: Progression of geotechnical units in WSU undergraduate civil engineering

It is generally acknowledged that geotechnical engineering is one of the more difficult civil engineering sub-specialisations to teach. Townsend (2005) attributes this to having to deal with the most challenging civil engineering material as opposed to water, steel, or concrete, considering that:
a) geotechnical engineering is very young (since 1930s), and theories are still evolving
b) underground soils are invisible, in contrast to structures, hydraulics, and transportation materials
c) soil behaviour is highly nonlinear, affected by stress history, and greatly affected by water

That said, the learning outcomes of geotechnical engineering at WSU, like the rest of engineering, are progressed in a structured way at three levels, namely: introduce, develop and assure. In the symbiosis of units shown in Figure 1, geotechnical engineering is progressed from “introduce” (Soil Mechanics and Pavement Materials and Design, Level 2) to “develop” (Engineering Geomechanics, Level 3) and then to “assure” (the “industry ready” specialised geotechnical electives, Level 3/4). The four geotechnical electives are required for students opting to specialise in geotechnical engineering, otherwise all civil engineering students will be taught at the minimum the core geotechnical units.

As mentioned in the above, the Soil Mechanics is the first contact with geotechnical engineering for almost all of our undergraduate students. It is an introductory unit covering the use of soil, and the water in it, as an engineering material, but it also provides students with a basic understanding of the physical and mechanical properties of soils, simple soil testing methods to characterise soil strength and deformation behaviour and how to apply basic techniques to assess the hydro-mechanical response of soils subjected to loading. This unit therefore mainly "introduces" the subject matter to students. It stresses fundamental soil mechanics concepts such as clay mineralogy, soil characterisation, effective stresses, shear strength of soils, lateral earth pressures, flow nets and consolidation theory that would be completely alien to the vast majority of the students since these topics are rarely, if ever, covered prior in high school syllabus. Contrast this with concepts of fundamental mechanics (e.g. statics and dynamics, vectors, forces, moments, equilibrium equations, free body diagrams etc.) where students especially those who aim to pursue engineering later at university, would have been taught at least some of these concepts in physics, applied mathematics or engineering mechanics at high school. A lack of prior knowledge in Soil Mechanics is another reason why it is harder to teach than other second year units.

Another challenge is to teach fundamental soil mechanics and higher level geotechnical units to students without strong underpinning mathematics and physics. Geotechnical units generally require knowledge of multivariable calculus which our students are weak in. This problem is not necessarily confined to WSU, but as mentioned earlier the particular profile of WSU students tends to amplify this problem. The failure rates of Mathematics for Engineers 2, originally a pre-requisite for Soil Mechanics, and covering ordinary differential equations and multi-variable calculus, were very high and still very high today. This held back the progression of a significant proportion of students, namely those who failed Mathematics for Engineers 2, from picking up second year units including Soil Mechanics, which in turn has a trickle-down effect on subsequent progression since the second year units form the basis of pre-requisites for higher level units. Realising that Mathematics for Engineers 2 was causing a severe choke point to student progression, some changes were introduced about four years ago. All bachelor of engineering students were asked to attempt a readiness test to allow them to move directly to Mathematics for Engineers 1 if they passed this test. The content of the unit consists of topics in arithmetic and algebra, trigonometry and trigonometric functions, logarithmic and exponential functions, differential and integral calculus. Students who failed this test must complete Mathematics of Engineers Preliminary as a pre-requisite before enrolling in Mathematics for Engineers 1. A review of the pre-requisites of all engineering units, particularly of the second year ones was also undertaken following which, it was decided to omit Mathematics for Engineers 2 as a pre-requisite for Soil Mechanics. Some of the teaching materials were revised to defer introducing some calculus-based concepts until later on. The passing rate for soil mechanics has since improved by about 5 percent.

Level 3 and 4 units: Engineering Geomechanics, Pile Foundations and Highway Infrastructures and their corresponding postgraduate units Advanced Geotechnical Engineering, Deep Foundations and Advanced Highway Infrastructures have been developed on the basis of project-based teaching and learning pedagogy. Here the projects are sourced from our industry colleagues who are also invited to give some guest lectures to inject additional industry perspectives. The challenge here, in our experience, is to establish a good balance between "providing sufficient guidance" and "requiring students to undertake research and exploration on their own". Too much of the former leads to "spoon-feeding" and too much of the later leaves student straggling in a confused state. Our experience is there is a tendency for students to seek examples of the solutions as a way of learning and completing the project assignments swiftly. Provision of examples is of course important to reinforce the process of learning, but equally students need to be properly taught the important concepts so that the knowledge can be transposed to solving problems in a different domain.

The geotechnical units specially make a point of addressing deficiencies in English language, report writing and use of common Office software by requiring all reports to be type-written using the Word processor, and charts and graphs to be plotted by Excel spreadsheet. A mentoring scheme is also available to all engineering students wishing to seek advice on managing their studies.

5. BOON AND CHALLENGES OF VIDEO RECORDINGS AND ONLINE TEACHING TOOLS

The availability of modern technology including videos and online teaching tools is generally a boon for teaching and learning in our experience, but it also presents some interesting challenges. All lectures at WSU are recorded on video by default. In Soil Mechanics, videos are also recorded of the laboratory tests students are required to perform during practical classes, as well as of some of the tutorials. Full lecture notes, laboratory notes and tutorial solutions are also uploaded online for all geotechnical units. The unit outline and learning guide provide detailed information on learning outcomes, assessments and contents covered, and teaching schedule. With all these information readily available to students with a click of the mouse, several connotations could be observed:

a) Students expect to be examined strictly according to the script, that is, questions not explicitly covered by way of examples in lectures or in tutorial questions even if based on the same principles and concepts emphasized in lectures are deemed unfair. As a result of this mindset, the performances of students suffer when concept type questions are being posed and examined.
b) Students expect step by step guidance for lab assignments and design projects, with very few showing much enthusiasm for doing their own research and exploration. When assignments and design projects requiring more independent work are posed, there would be a push back by students and reflected in negative comments in the student feedback.
c) Due to teaching materials being available online, including lecture video recordings, the attendances at lectures are quite poor, and tend to drop off even more towards the second half of the semester. Notwithstanding this, it is also noticed that the viewership of the lecture videos is not particularly high either, so it would suggest that students are mainly studying first and foremost by reviewing the tutorials and examples in the lectures, then the lecture notes. This “short-cut”, “fast-tracked” learning mindset undermines mastery of the concepts and in-depth understanding of the subject matter in geotechnical engineering. It would appear that the “spoon-feeding” approach to teaching and learning is becoming more prevalent and, most importantly, is sometimes being demanded by students.
d) Plagiarism continues to be an issue when information is so readily sourced through the internet. We have encountered incidences where geotechnical design projects were uploaded online for tender in exchange for cash payment.

Some of the above challenges and issues arose because WSU has not been able to attract enough of the best and brightest students. However, this should not detract from its mission to encourage widening participation in geotechnical engineering from students in the lower socio-economic groups. These are not necessarily mutually exclusive goals.

6. CHALLENGES OF MULTI-CAMPUS TEACHING

These challenges are more unique to WSU than most other universities. Geotechnical engineering is taught at 3 different campuses at WSU: Penrith, Parramatta South and Parramatta City. A fourth campus managed by a private vendor but using the geotechnical engineering teaching materials under supervision by WSU is located in the heart of Sydney City. Multi-campus teaching of geotechnical engineering presents quality issues.

A critical quality issue is that of assessment, especially in the case of our Sydney City campus since it runs independent examination and assessment separate from the other three campuses. Here, assuring uniformity of assessment across campuses is one of the challenges which stretch the imagination of the unit-coordinator. Mid-semester examinations which are organised by the academics instead of the university’s Assessment and Graduation department requires multiple versions of the exam papers to be prepared to cater for multiple campuses and sittings at different times. The authors’ personal experience suggest that this creates an opportunity for an early version of paper in an earlier sitting to be photographed by a mobile phone or like device, and posted for sale to students sitting in latter sessions. This is made possible by the communication technology available today, hence, it is absolutely necessary to set different versions of questions for sittings at different times. Not only does this create a strain on the academics in having to prepare multiple versions of the mid-semester examination questions hence additional workload, it is also problematic to achieve a level of consistency.

The second issue is the duplication of resources across the campuses. A second geomechanics laboratory for undergraduate teaching was set up at our Parramatta campus in addition to the one at Penrith campus. The duplication of resources meant less funds are available for upgrading of both laboratories. It is also an irritant when resources are moved from the laboratory on one campus to the second to cater to ad hoc needs and not returned.

7. CHALLENGES IN FUTURE

A review of curriculum and course content is needed to prepare students who are both strong in the fundamentals as they are “industry ready” for the work force. For a start, WSU needs to attract the best and brightest students into engineering and eventually some of them into geotechnical engineering, apart from widening participation from students of lower socio-economic groups. It is necessary to teach our undergraduates that geotechnical engineering is not just about simple soil tests and plugging numbers into equations.

Our students should be taught to understand the fundamental concepts and apply these in a reasoned way to solve geotechnical problems outside of their familiar domain. That is, it is not simply a regurgitation of the formulas and familiar solutions of those problems gained from experience, but also in applying their knowledge analytically to deal with challenging problems outside the box.

Our postgraduate courses must be organized to be flexible, adaptable to changing industry needs and incorporate best industry practices. For this to happen, universities must also balance recruitment of academics on the basis of their ability to teach the practice of engineering armed with relevant industry experience especially in geotechnical design and construction, with the metrics on research funding and publications. Industry practice must be infused into problem based teaching culminating in capstone projects. The future could be one where engineers need to return to the university for re-training, perhaps as often as once every decade, in order adapt to technological advances especially in the age of A.I. Hence we see WSU as having an important role to play in contributing to the continuing professional development of practitioners from industry. Besides embedding industry relevant geotechnical units into the civil engineering program, WSU can also update the geotechnical practitioners by running specialist short courses or “refresher courses” on basic topics such as site investigation, ground improvement, bearing capacity, settlement etc. The age of lifelong learning is never truer than today. The use of technology can help in the delivery of the geotechnical courses to cater to changing industry needs.

8. CONCLUSIONS

WSU, being located in one of Australia’s fastest growing and most diverse region has a special role to play in contributing to the training of geotechnical engineers. The special circumstances of being in a region of relatively lower socio-economic status, the impact of new and emerging technologies, multi-campus teaching, difficult subject matter and meeting industry needs combine to create a set of challenges, though not necessarily unique, is perhaps more pronounced than that faced at other universities. Solutions proposed at WSU to address some of these challenges are also discussed.

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Building Certification Process: Educational Aspects – A Review

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Abstract

This paper presents a review of the procedures involved in the building certification process with a special focus in New South Wales. It has been found that building certification process is a complex process where differences may happen between the owners and certifying authority due to lack of communication. The civil engineering students in the university are not well aware of the building certification process in a greater detail. It is an art that is to be learnt when a learner works under an expert certifier. It is recommended that civil engineering students should get few lectures on building certification, which could assist them to become a better construction and design engineer.

Keywords: Building certifier, private certifier, council, engineering, learning

INTRODUCTION

Building certification is an important research topic (e.g. Aktas et al., 2015; Gandhi and Jupp, 2014; Ugur and Leblebici, 2017; Zuo et al., 2017). Building regulation and certification are a significant part of the NSW planning system. The general outcomes that regulation and certification seek to secure are two-fold. Firstly, a level of building performance consistent with the needs of an advanced society in terms of health, safety, amenity and sustainability and secondly compliance consistent with planning expectations as defined by the planning system. The current system of certification has evolved from the introduction of private certifiers in 1998, enabled by amendments to the Environmental Planning and Assessment Act 1979 (EP&A) and Regulations.

Quality of buildings, administrative changes were put in place within Department of Urban Affairs and Planning for regulatory oversight of certifiers and in 2005 the Building Professionals Act established the Building Professionals Board (BPB), which took over this function. Subsequently, there have been numerous legislative amendments and changes to regulations relating to certification. These have been essentially accretive and so the legislative framework has become unnecessarily complex and in some cases no longer relevant.

With the establishment of a new planning system, the opportunity presents to take a fresh look at arrangements which have essentially developed as flow-ons from the last major reforms dating back to the 1979 commencement of the EP&A. Accordingly, the well-established principles of developing regulatory systems that are efficient in an economic sense, as well as effective having regard to ease of administration, achievement of desired outcomes and minimizing the compliance burden, should now be applied.

Local governments were responsible for building certification process and concerns were often raised about costs and delays under this model. In later years building certification in the state has been privatised. Privatisation occurred to improve the efficiency and flexibility of the building certification process. Building certifiers provide a regulatory oversight role in the building industry, helping to ensure that building codes and standards are adhered to and buildings are constructed safely and fit for its intended purpose.

Current model of building certification allows customers to seek certification services from a range of licensed and accredited private building certifiers or from their local government. There are no standardised fees for certification services, allowing customers to find the best price and range of services that meets their needs. There are no rules in the state about who may engage a private certifier. Generally, this is done by the builder or sometimes the property owner/developer.

An owner can also engage a certifier; however this is not common practice. All other Australian jurisdictions currently have one form of private certification, and the majority has a dual model, which includes the additional option of local government certification.

BUILDING CERTIFICATION BACKGROUND

The Complying Development Certificates and Construction Certificates must be determined by a Principal Certifier (PC), unlike Development Applications which can only be approved by Council.
Once the local government or individual certifier obtains development consent, you are required to appoint a Principal Certifier to issue a Construction Certificate and undertake inspections.

WHAT IS A PRINCIPAL CERTIFIER

A Principal Certifier is the person or authority responsible for ensuring compliance with the conditions of development consent, the Building Code of Australia, and the objectives of the Environmental Planning & Assessment (EP&A) Act 1979.

A PC is required to:
• Ensure compliance with the conditions of consent
• Issue the Construction Certificate
• Conduct inspections at each required critical stage of construction
• Promptly advise the applicant, after each relevant inspection, of any outstanding work
• Issue the Occupation Certificate.

PRIVATE CERTIFIERS AND LOCAL COUNCILS

When the certification function was partially privatised with the legislated introduction of private certifiers, the boundaries between the functions of Councils (extending beyond certification) were not clearly drawn.

The policy intention was to create competition between the private sector and local Councils for the provision of certification services. Now, private certifiers are well established and their market share is estimated to be well in excess of 50% of the building approvals market by value (estimates range as high as 70%, although there is no reliable data) and probably around 50% by number.

Most councils accept that private certifiers are here to stay, but there are tensions. These tensions arise in a number of areas. First, there is a perception among stakeholders consulted for purpose that private certifiers are not adequately supervised or disciplined and that complaints are not dealt with in either a timely or satisfactory fashion.

Further, the highly prescriptive regulations dealing with investigations by the Building Professionals

Board result in a high threshold for raising complaints (requirements for statutory declarations and extensive documentation). Complaints take too long to resolve and are sometimes dismissed on technical grounds.

This leads to the second area of concern, that Councils are left to "pick up the pieces" when things go wrong and suffer a public loss of confidence because the community looks to them to resolve these sorts of issues.

Another area of concern is that Councils have lost control of consent compliance. Some appear to stand back when a private certifier is appointed because they feel that any consequences flowing from the actions of private certifiers should be the province of the State.

In addition, some stakeholders believe that private certifiers rarely report cases of non-compliance to Councils. On the other hand, there appear to be instances where private certifiers (who for the most part are former Council employees) work cooperatively with local Council inspectors.

Whether the "level playing field" contemplated by policy-makers who thought the principles of competition policy should apply in this area, either exists or is achievable is a moot point. Certainly there are many imperfections in this "market".

Council employees who undertake the provision of certification services invariably take a more holistic view of their role. They tend to be, first and foremost, employees of Council who regard the interests of their local community as their priority. So enforcement of consent conditions and local environmental issues go hand in hand with the certification function. This appears to be the case even in Councils which have separated their certification function and sought to run it on business lines to compete with the private sector.

BENEFITS OF A CERTIFCATION MODEL

• Less of a perceived conflict of interest for certifiers.
• There would be a "one-stop-shop" for consumers in the first instance.
• Standardised fees would allow for greater consistency and confidence in estimating project costs.
• Some projects could be subject to lower certification fees based on a standardised fee structure.
• Certifiers would be entitled to an equitable share of certification work.

OPPORTUNITIES

The introduction of a tougher building regulation regime is essential if code based assessment and private certification are to be expanded. There are a number of issues with building certification and regulation that need further analysis and resolution.

These problems stem largely from the unclear roles and responsibilities of all players and a lack of regulatory clout and oversight of the entire process by the Building Professionals Board (BPB).

The private certification system has a poor track record with respect to issuing certificates that are significantly inconsistent with consents, failing to detect and act on unauthorised work; and certifying incorrect plans or incorrectly applying BCA/Regulations.

The BPB has been criticised for a lack of disciplinary action in response to complaints about certifiers. While there is broad support within the Local Government sector for the changes, there are specific details and practical implications that will need to be resolved.

Not-with-standing the outcome of the current debate, it is critical that Local Government expertise is sought during the development of any policies, guidelines, regulations and detailed implementation.

INSURANCE ISSUES

One consequence of increasing the regulatory burden of the certification process is the impact on the cost and availability of professional indemnity insurance for certifiers.

This in turn could have a major bearing on the willingness of practitioners to remain in the certification business or for new entrants to commence. Building surveyors are sometimes employed by businesses which provide a range of services, including consultancies to the construction industry.

Sometimes decide to withdraw from practicing as certifiers because of increased liability (or perhaps because their employer has chosen to focus on other areas).

Also, some insurers have indicated that Professional Indemnity (PI) cover for building certifiers is for them a marginal business proposition and recent changes may result in them abandoning this type of cover.

There are other insurance concerns. While continued or "run off" cover is available to certifiers who retire or leave the industry, few avail themselves of this cover presumably because of its cost, apparently choosing to expose their personal balance sheets in the case of claims made in relation to jobs completed while they were working.

This means that parties who may wish to make claims have limited recourse. In addition, there is the issue of continuity of cover over the life of a particular project. In the event that a certifier abandons a job for whatever reason, a subsequent appointment of a certifier results in gaps in cover. The BPB has explored the possibility of obtaining group cover to apply to these types of situations, seeking consultancy advice. However, their advice was that without relevant data, insurers would be unlikely to write this type of business.

BASIC CERTIFICATION PROCESS

Preliminary consultation and preparation
Research your proposal and prepare your application documentation using our Property Enquiry.
Use the residential development application checklist to ensure you include all the required information in your Development Application.
Have a question? Contact our Customer Service Centre on 02 4921 0333.
Attend a Pre-Lodgement Meeting (only medium or major applications).

Lodgement
Lodge your application at our Customer Service Centre counter or by mail at a Lodgement Interview (medium or major applications)

Notifications and submissions
Notify adjoining properties (where applicable).
Undertake internal and external referrals if required.
Provide progress of your application through Application Tracking.
Make submissions received available for viewing on the internet.

Assessment
Undertake a site inspection.
Complete formal assessment against relevant legislation.
Liaise with applicant if further information is required.
Complete a report with recommendation for:
approval (with conditions)
refusal (with reasons)

Determination
A delegated officer or the elected Council will determine the application.
Written notice is provided to the applicant and objectors.
If dissatisfied, the applicant may seek:

Review of Determination
Modification of Consent
Appeal to the Land & Environment Court

Construction Certificate
Appoint a Principal Certifying Authority (if not already appointed).
Obtain a Construction Certificate from Council or another accredited certifier, before work commences (if not already obtained).
Ensure mandatory inspections are undertaken and certified by the Principal Certifying Authority.

Development commencement
Lodge Notice of Commencement at least two days prior to commencing works.
Undertake construction in accordance with your DA and CC approved plans and conditions.
Ensure mandatory inspections are undertaken and certified by the Principal Certifying Authority.

Development occupation/use
Undertake a final inspection and issue an Occupation Certificate when construction is completed and considered compliant.
The building should not be occupied prior to an Interim or Final Occupation Certificate being issued.

CONCLUSION

Accredited certifiers vary in their practices regarding standards adopted and which matters are addressed during mandatory site inspections. This contributes to a lack of confidence in the certification system. There is a poor understanding in the community of the role and desired outcomes of certification. There are gaps in the licensing and accreditation system for building practitioners making it difficult to hold some builders accountable. Current legislative provisions fail to distinguish between certification regarding building standards or consent conditions relating to the built form and the quality of work, leading to consumer confusion. The role of Councils is unclear in relation to enforcing the conditions of development consent. Councils are sometimes reluctant to become involved in enforcement where a private certifier is involved. While there is a lack of data, there is evidence to suggest that certifiers are being joined in actions against builders.

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Deterioration of Groundwater Quality by the Actions of Percolation and Leaching from Nala-Lai in Rawalpindi Region, Pakistan

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Abstract

This paper presents a case study on the impact of Nala Lai wastewater in Pakistan on potential contamination of its nearby tube wells, bore water, dug wells and springs through percolation and leaching routes. Nineteen wastewater samples from Nala Lai stream and 68 groundwater samples from its associated and nearby areas were collected during (Season) and were analyzed for different water quality constituents. The parameters which were analyzed for determining the water quality include physiochemical parameters like Biological Oxygen Demand, Chemical Oxygen Demand, pH, temperature, turbidity, color, hardness, dissolved Oxygen, electric conductivity, total dissolved solids, Sulfates, Chlorides, Hardness and globally alarming heavy metals such as Cadmium, Cupper, Iron, Zinc, Manganese, Lead as well as bacterial parameter were recorded too. The results confirmed that all the 19 samples of surface water samples collected from Nala Lai exceeded the desirable limits (by NEQS) of both BOD and COD parameters.

Keywords: Groundwater, Wastewater, Nala Lai, Percolation, BOD, COD, E.coli.

INTRODUCTION

Groundwater contamination is a very noteworthy environmental concern of the time (Momodu and Anyakora, 2010). Regardless of its importance, groundwater resource is not properly managing in earth (Fakayode, 2005). There are various probable sources of groundwater pollution in cities including point, non-point and linear sources. Point sources include industrial effluents, domestic sewage and storm overflow, non-point sources include construction work, agriculture activities and atmospheric deposition and linear sources are roads and sewer system (Choi et al., 2005).

The presence of emerging organic pollutants can be well examined and analysed in wastewater and surface water as compared to groundwater. Emerging organic pollutants major source is wastewater whereas surface water carries their maximum load (Pal et al., 2010). Approximately 2.3 billion populations across the world is suffering from diseases related to polluted water (UNESCO, 2003). Worldwide, approximately polluted drinking water and insufficient sanitation kill 1.6 million children below the age of five years and 84% of them are residing in villages (Hisam et al., 2014). Water contamination is the dominant health and environmental issue in Pakistan. The main sources of groundwater pollution in Pakistan are the discharging of waste effluents into water bodies by many industrial units including textile, fertilizers, pesticides, steel, dying chemicals, cement, leather etc (Tariq et al., 2006).

In Pakistan 20-40 % hospital beds are occupied by the patients of waterborne diseases like diarrhea, hepatitis, typhoid, dysentery, cholera etc. One third of all deaths occur across the country owing to waterborne diseases (Farooq and Hashimi, 2008). Heavy metals presence in drinking water can damage vital organs i.e. kidney, liver and central nervous system. They also cause abnormality in blood composition (Khan et al., 2011). The perennial wastewater of Nalla can be more vulnerable to groundwater quality deterioration of nearby tube wells and boreholes. The underground lithological environment is the principal influencing factor of contaminant migration to groundwater (Rahman, 2008). The present study is conducted with the prime objective of surface wastewater characterization in Nalla Lai and identification of vulnerable tube wells, boreholes and springs which are being contaminated by Nalla Lai and comparing the analyzed results with WHO and NSDWQ standards and providing guidelines for future studies.

STUDY AREA

The study area, Rawalpindi city is located between 72º 38′- 73º 37′ E and 33º 04′- 34º 0′ N, longitudes latitudes (Shabbir and Ahmad, 2015). It is the third largest metropolitan area of Pakistan with a population of about 3 million inhabitants. The climatic of Rawalpindi is humid subtropical with hot long summers and short monsoonal wet winters. Annual rainfall occurs mostly in summer monsoon season is 39 inches (990 mm) (Dino et al., 2011). Both Soan and Kurang rivers are the main water reservoirs draining the city (Wardlaw, Martin, Haydri, 143). The elevation of water table decreases from 600 m at the foot of Margala hill (F-7 sector Islamabad) to 450 m in the vicinity of Soan river. The major environmental problems of the city are pollution of surface and ground water resources due to inappropriate solid waste dumping sites and improper sanitation (Nisar et al., 2008).

RESULTS AND DISCUSSION

The physico-chemical and microbiological parameters of groundwater in the vicinity of Nalla Lai and characterization of surface wastewater of Nala Lai revealed that many parameters of groundwater and wastewater samples were exceeding the standard values of NSDWQ, 2010, WHO and NEQ's,1997. The elevated results of groundwater contaminants were directly linked with surface wastewater percolation from Nala Lai. Geo-chemical study of soil strata showed that traces of heavy metals that may be polluting the chemistry of groundwater (Haq et al., 2007). Groundwater sampling of study area was categorized into three zones (upstream, midstream and downstream) for convenience and their statistical results are given in Table 2 and 3. Total (14) tube wells, (19) boreholes, (2) springs and (1) dug well samples within 100 meter distance along both sites of Nala Lai were tested for physico-chemical and microbiological analysis whereas (10) control samples of bore water and (3) tube well water samples were also tested. Results of some of the important water quality parameters are discussed below.

pH

The average value of pH in 49 groundwater samples was 7.30 while the average pH value in 19 wastewater samples was 7.72. pH value in groundwater and wastewater samples were ranged between 6.4 - 8.21 and 7.54 - 7.97 respectively. pH value in three borewater samples of study area was declined towards acidity and exceeding the standard values when compared with NSDWQ, 2010 and WHO. The pH value of all wastewater samples was within the range of wastewater standards NEQ's (1997). Similar conclusion was also deducted by Nasrullah et al. (2006) during analysing the industrial effluents and groundwater of Swabi. The pH of wastewater samples of study area was slightly declined towards basicity due to maximum load of organic pollutants in wastewater stream of Nalla lai. pH value specifies the acidity and basicity of water (Dohare et al., 2014). According to (JICA, 2005) when pH decreases in water then metals solubility increases.

Temperature

The average value of temperature in 49 groundwater samples was 22.73 °C while its average in 19 wastewater samples was 27.1 °C. Temperature value in groundwater and wastewater samples were ranged between 20 °C- 27 °C and 20 °C-29 °C respectively. Temperture values were below the permissible limit in all wastewater samples when compared with NEQS, 1997 standard. Temperature values of the wastewater were almost similar with the ambient air temperature. As reported by Nicholson et al. (2016) air temperature has a slight effect on groundwater but key effect on surface water of low velocity (Nicholson et al., 2016). Temperature plays a key role for the detection of bacterial contamination (Ahemd et al., 2013). This implies that in summer season the thermotolerant coliform can easily grow and survive in Nalla Lai and finally percolate with other pollutants to contaminate groundwater of the study area. As described by Akbari et al. (2017) temperature is a significant indicator of water quality in relation to the existence of aquatic life.

Turbidity

Turbidity value of 49 groundwater samples was zero. The average value of turbidity in 19 wastewater samples was 3228.48 NTU. Turbidity in wastewater samples were ranged between 2057.11 NTU-4547.34 NTU. Highest value of turbidity in Nalla lai was observed in sample 1 which carries waste effluents of I-9 industrial area Islamabad. Similar kind of results was also drawn by Tariq et al. (2006) after characterization of hayatabad industrial effluents and groundwater of peshawer. Due to domestic, commercial and industrial effluents in wastewater of Nalla Lai the turbidity value was very high. High turbidity level affects DO level in water or wastewater stream and creates oxygen deficiency and finally affect the survival of aquatic life. Turbidity relates to the cloudiness of water. High turbidity in water occurs due to different impurities like silt, wood ash, coal dust, microorganism or chemicals (Akhtar et al., 2014). Turbidity occurs due to the presence of colloidal and very fine dispersions (Srivastava and Pandey, 2012).

DO

The average value of DO in 49 groundwater samples was 5.49 mg L^{-1} while the average value of DO in 19 wastewater samples was 0.96 mg L^{-1}. DO values in groundwater and wastewater samples were ranged between 2.74 mg L^{-1} - 8.55 mg $L^{-1}$and 0.15 mg L^{-1}- 2.96 mg L^{-1} respectively. According to Balamurugan et al. (2012) dissolved oxygen is a significant indicator in the judgment of water quality. It reflects both physical and biological processes prevailing in water bodies. The DO level signifies the level of pollution intensity in water. Dissolved oxygen is the amount of gaseous oxygen dissolved in water body through any source (Prajapati and Dwivedi, 2016). Low DO level in wastewater stream of study area was analysed due to high load of pollution level. In other words the wastewater stream of study area contains high level of both organic and inorganic substances due to which low oxygen level and high BOD and COD level was observed during analysis.

EC

The average value of EC in 49 groundwater samples was 592 µ S/cm while the average value of EC in 19 wastewater samples was 1402.05 µ S/cm. EC values in groundwater and wastewater samples were ranged between 202 µ S/cm- 1388 µ S/cm and 1242 µ S/cm- 1557 µ S/cm respectively. The analysed results of EC were higher from the results drawn by Tariq et al. (2006). Average EC value of the study area was higher from the previous study conducted by Haq et al. (2007) on groundwater contamination of Rawalpindi. The higher level of EC in wastewater of study area revealed the elevated level of dissolved ions concentration in wastewater of Nalla Lai from the previous years. As mentioned by Nasrullah et al. (2006) electric conductivity measures the ability of water to pass an electric current. EC level depends on the mobility of free ions.

TDS

The average value of TDS in 49 groundwater samples was 471 mg L^{-1}. TDS values in groundwater samples were ranged between 162 mg L^{-1} - 1007 mg L^{-1}. TDS indicates water quality and salinity (Pande et al., 2015). TDS was detected in elevated concentration from the standard value in only one bore water sample which was located within 100 meter distance of Nalla Lai. High concentration of TDS in the water sample showed that pollutants are percolating from surface wastewater of Nalla Lai. As observed by Choi et al. (2005) the TDS values were increasing in ascending order i.e. forested areas < agriculture land < residential area < traffic site < industrialized zone respectively. TDS concentration above 1000 mg L^{-1} is considered unsuitable for drinking purposes (Akhtar et al., 2014). The water quality of sample 13 is not suitable for drinking purpose due to elevated level of TDS from the set standard. TDS is the indicator of water suitability for different types of uses. High level of TDS affects water taste, hardness and corrosive property (Akhtar et al., 2014). Total dissolved solids include minerals, salts or metals dissolved in water (Sagar, 2015).

Sulfate

The average value of Sulfate in 49 groundwater samples was 25.3 mg L^{-1} while its average value in 19 wastewater samples was 23.59 mg L^{-1}. Sulfate value in groundwater and wastewater samples was ranged between 13.9 mg L^{-1}- 91.6 mg L^{-1} and 19.81 mg L^{-1} - 27.21 mg L^{-1} respectively. Sulfate value was below the permissible limit in both groundwater and wastewater samples when compared with NSDWQ, 2010, WHO and NEQS, 1997 standard values. Rashid et al. (2014) reported that Sulfate level was exceeding from the standard value of NEQ's (1997) in wastewater samples collecetd from effluents of paper and pulp industries of Pakistan. Sulfate was not found in high concentration in our study area due to the fact that no anthropogenic source of Sulfur was identified. As described by Miao et al. (2012) Sulfate occurs largely in both natural and anthropogenic water supply. Industrial and domestic discharges can increase its concentration level (Srivastava and Pandey, 2012).

Lead

In groundwater samples Lead was detected in only one sample above the BDL (Below Detection Limit) value. The average value of Lead in 3 wastewater samples was 0.15 mg L^{-1}. Lead was detected in only three wastewater sample. Lead in wastewater samples were ranged between 0.01 mg L^{-1} - 0.27 mg L^{-1}. Lead is common element exist in earth's crust and its minute concentration is naturally occurring in soil and water (Raviraja et al., 2008). Lead contamination occurs in drinking water through different sources like domestic paints, vehicular emissions and wastes from industrial activities (Haq et al., 2009). Long term exposure to lead can leads to several diseases and harmfully affect vital organs such as nervous system, digestive system, cardiovascular system, Haematopoietic system, reproductive system, immunological system, kidneys and skeleton as well (Gidlow, 2004; Venkatesh, 2004).

BOD

The average value of BOD in 19 wastewater samples was 119.15 mg L^{-1}. BOD of wastewater samples ranged between 90 mg L^{-1}- 186 mg L^{-1}. BOD of all wastewater samples was exceeding the standard value of NEQ's, 1997. BOD results revealed the presence of high concentration of organic pollutants in surface wastewater of Nalla Lai. BOD determines the amount of oxygen utilized by aerobic bacteria or microorganism to decompose organic matter. It measures the load of organic matter in a stream and quantifies the level of dissolved oxygen (Auju, 2015).

E.coli

Thirty-three groundwater samples were tested for microbial analysis. The results revealed that 26 samples showed fecal contamination including 9 tube wells, 12 bore water, 2 springs and 1 dug well located within 100 meter distance along both sites of Nalla Lai. Ground water of microbially contaminated localities can cause waterborne disease. The results clearly revealed that wastewater is percolating from Nalla Lai to ground water in its vicinity. Microbiological contamination in water is a major cause of water-borne disease i.e. typhoid, diarrhea, dysentery, nausea, gastroenteritis and other health-related diseases (Shahid et al., 2015). The main source of bacterial contamination in groundwater is because of Nalla Lai. Due to puncturing of underground rocks from different locations bacteria can find route and easily access to the groundwater table (Haq et al., 2007). Two control samples are also found with fecal contamination. Un-treated domestic wastewater is also causing microbial contaminating in groundwater (Haq et al., 2007). Figure 1 shows the E.coli results in the study area.

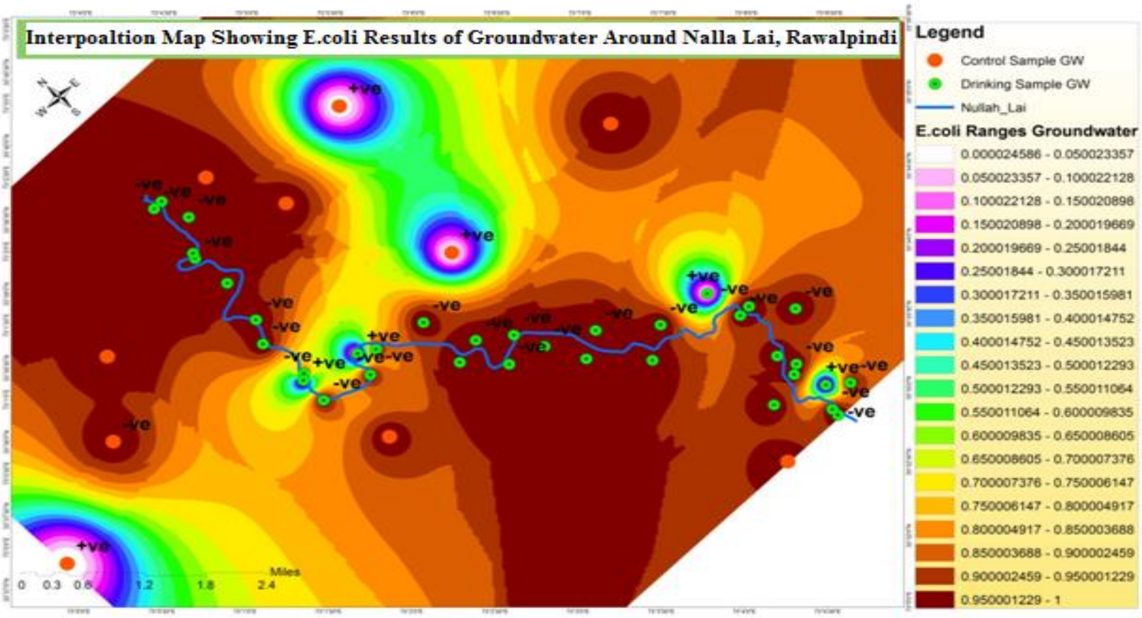

Figure 1: E.coli results in the study area

CONCLUSION

The study identified many physico-chemical pollutants in high concentration in both surface waste water of Nalla Lai and shallow (Bore water, Dug well and springs) and deep groundwater (Tube well) in the vicinity of Nalla. The research work revealed that certain heavy metals are percolating from surface wastewater of Nalla and contaminating the nearby tube wells, bore water, springs and dug well water. Similarly, microbial contamination was also detected in groundwater samples collected from the proximity of Nalla Lai. Maximum concentration of heavy metals in both groundwater and wastewater samples was observed in upstream locality of study area. The research also highlighted that sample (1) and sample (2) are potential sources of elevated concentration of pollutants in wastewater of Nalla Lai which finally percolates into groundwater. These wastewater samples were collected from two different channels carrying sewage as well as industrial effluents of I-9 and I-10 sector Islamabad and finally mix with each other at the point of Kataria Bridge (Starting point of Nalla Lai). Likewise, sample (2) (Bore water), sample (28) (Dug well), and sample (35) (Bore water) are highly vulnerable groundwater localities in terms of physico-chemical and microbiological contamination. There is a dire need to cope with the issue by responsible authorities by installing tube wells, boreholes and dug wells at least 300 meter distance away from Nalla Lai to prevent any type of percolation and leaching of contaminants from wastewater of Nalla Lai. The responsible authorities should take concrete initiatives to ensure public health by providing safe drinking water through protecting groundwater resource of Rawalpindi by enforcing environmental regulations.

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Algal Bloom in Australian Rivers: A Review

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Abstract

Eutrophication, caused by algal bloom is one of the major concerns for water quality in the Australian rivers and other water bodies. Excessive growth of algal blooms in water bodies would significantly alter the pH, colour and concentration of dissolved oxygen in water, making it unsuitable for many intended purposes. For example, fishes would not be able to survive in the river and swimmers could face undesirable dermatological issues. Also, harmful algal blooms could make the water unfit for drinking, household use, sanitation and irrigation. These algal blooms are mainly caused by excessive supply of nutrients (nitrogen and phosphorus) into the water bodies. This paper presents a review of major incidences of algal blooms and its effect as eutrophication in Australian water bodies. Nitrogen is frequently considered as the limiting nutrient, however, phosphorus is also an important nutrient for eutrophication management. Nutrient emissions from anthropogenic sources also enrich marine waters and encourage the growth of plankton. Studies showed that the nitrate concentrations in rivers must be limited to between 5 and 15 mg/L, depending on the bay, to reduce Ulva biomass by half on the coast. Control and management of cultural eutrophication is a complex problem and requires the collective efforts of scientists, policy makers and citizens to reduce nutrient inputs, develop effective, long-term biomanipulation techniques and to ultimately restore aquatic species.

Keywords: Algal bloom, cultural eutrophication, limiting nutrient, Australian water bodies.

1. INTRODUCTION

Algal bloom is one of worst environmental threats to the health of Australian water bodies. In particular, this is an important issue in lakes where water is relatively stagnant and which receives runoff from agricultural lands. There has been evidence of algal bloom in the Warragamba reservoir, which is a source of about 90 percent of water supply for Sydney region. Although the mechanisms responsible for cyanobacterial algal blooms are not well understood, the link with enrichment of nutrients has been widely recognized and investigated. For example, the observed relationship between cyanobacterial blooms and nutrient imbalances suggested that the 1999 bloom in Myall Lakes could have been caused by anthropogenic nutrient effects. Dasey et al. (2004) postulate the anthropogenic sources of nutrients in the lake are as the farming in the watershed and sewage discharges into the river Myall. Further, Palaeo lake records studies are producing an expanding number of sites, subject to anthropogenic nutrient effects (Schelske & Hodell, 1991; Bennion et al., 1996; Umbanhowar et al., 2003; Bennion et al., 2004), which are associated with agricultural activities such as ploughing, dairy farming and the use of fertilizers (Talbot, 2001).

A climatological condition of drought (Li et al. 2017), presence of an optimum amount of Nitrogen (N) and Phosphorus (P) ratio for algal growth (Conley 2009), a high amount of N and P in fertilizers (Smith 1999) and the release of household detergents are main contributing factors for algal bloom outbreaks in Australian waterways. Hence, drought prone areas, waterways with close proximity of farming lands and linked to household sewage lines, and stagnant waterbodies are usually at high risks for algal bloom outbreak in Australia. Certain environmental factors such as temperature, salinity, sunlight, nutrient levels, flow in waters and presence of predators or grazers may directly affect the growth of algal bloom in water.

Studies observe that direct contact or ingestion of water containing algal bloom can cause minor to serious effects on public health, such as eye and skin irritation, nausea, vomiting, abdominal cramps, gastroenteritis, diarrhea, anorexia, dizziness, headache, confusion, tingling, muscle aches, fatigue, sore throat, rash, fever, muscle/joint pain, malaise, weakness (Hilborn et al. 2014). For example, Dodds et al. (2009) reveal that the annual financial loss due to eutrophication in the U.S. alone is about $2.2 billion.
This paper intends to review major algal bloom incidences in Australia and in some other parts of the world. The paper also looks into the eutrophication modelling techniques and highlights on the control mechanism for algal bloom. The outcome of this study would be useful to further understand the effect of algal blooms in Australian water bodies and its management interventions.

2. MAJOR INCIDEENCES OF ALGAL BLOOMS IN AUSTRALIA

Australia, for many years was known as a clean and green farming nation. However, the algal bloom attacks in Australian river system has struck a severe blow to this reputation. The first ever riverine algal bloom attack was observed in Darling River in 1991. About 1000 km long stretch of the river was affected, which is reported to be one of the longest riverine blue-green algal bloom attacks in the world (Donnelly et al. 1997). Due to this severe environmental disaster, the livestock system of New South Wales (NSW) suffered a setback and a state of emergency was declared. This event shook up the whole nation. Subsequently, significant amount of funds were allocated to do water research by the State and the Federal Governments of Australia to find out the causes and remedies of algal bloom attack. Table 1 and 2 summarizes the major incidences of algal bloom occurrences in Australia and the rest of the world.

Table 1: Instances of algal bloom occurrences in New South Wales

River/lake name	Algal bloom affected period	Affected area	Comments	References
Darling River	1991	1000 km	First instance of algal bloom attack in Australia. One of the world largest riverine algal bloom attacks. A state of emergency was declared.	The Conversation (2016) Donnelly et al. (1997)
Myall Lakes	1999-2001	4 lakes	Lakes water affected by highly toxic cyanobacterium	Drew et al. (2008); Water NSW (2004, 2012)
Warragamba Reservoir	2007	58-60 km	Half of the dam water was affected. Happened after about 8 years long drought.	Benson (2007)
Murry River	2007, 2009, 2010, 2016	1000-1700 km	Prone to repeated algal bloom attacks.	The Conversation (2016); Water NSW (2009)

Table 2: Algal bloom incidents around the world

Site	Bloom type	Comments	Affected period	Reference
US/ North American west coast	Dinoflagellates (red tides)	Killed fishes early but now a days became lethal to human also	1996-Present	Lewitus et al. (2012); Horner et al. (1997)
New England	Dinoflagellates (red tides)	Killed shellfish and huge amount of financial loss by fisherman	1972	Anderson (1989)
Lake Ontario, Great Lake, Lake Winnipeg, Canada	Cyanobacterial blooms	Most of the blooms produces toxins and Lake Winnipeg named as “Canada’s sickest Lake”	2005-Present	Pick et al. (2016)
Chesapeake Bay, Virginia, USA	Harmful Alexandrium monilatum	Multimillion dollar loss in oyster aquaculture industry	2007	Pease et al. (2015)
Brittany, France	Green microalgae	Nitrogen from intensive farming were dumped in the Brittany lakes	2009	Perrot et al (2014)
Qingdao, China,	Harmful Algal blooms	7,335 tonnes of algal blooms were removed from the river	2013	Yuan et al. (2017); The Guardian (2013)
Southeastern Coast, Brazil	Myrionecta rubra algae	Produces different types of toxins which is harmful for human	2014	Alves and Mafra (2018)
Toledo, Ohio	Blue-green algae	Put 500000 inhabitants in severe scarcity of water	2014	Berry et al. (2017)

The mechanism behind excessive cyanobacterial growth in Myall lakes water during 1999 (Figure 1) have not been well identified. It is hypothesized that the anthropogenic nutrients enrichments in Myall lakes from agricultural activities around the lakes were the main reasons behind the growth of highly toxic cyanobacterium *Anabaena circinalis* Rabenhorst (Dasey et al. 2004).

Warragamba reservoir was contaminated with blue-green algal bloom during the period of March-September 2007 after a long-standing of eight years drought when the level of water in reservoir has reached all-time low (Figure 2). Half of the reservoir was affected by algal bloom and the water suppliers forced to collect the water from 37-42 meters from its surface level to make the water drinkable for consumers (Benson 2007).

Figure 1: Algal bloom in Myall Lakes (1999). (Source: Water NSW 2004)

Figure 2: Algal bloom in Warragamba reservoir (2011) (ABC 2011)

The conversation (2016) reported that the Murry River was seriously affected by algal bloom in four instances during the period of 2007-2016 (Figure 3). About 1000 square km area was contaminated with algal bloom in 2007 while 1700 km surface of Murry River was affected during 2016. It has been observed that the Murry River is more prone to the algal bloom attack that any other river in NSW. A few possible causes were examined for this. Despite the fact that summer air temperatures were among the hottest on record, no significant links between the meteorological factors and bloom abundance were found. Rather, a weak but noteworthy relationship was found between the surface water temperature and bloom abundance in the downstream of Lake Hume, as the hot weather is likely to have led to higher water temperatures promoting development of blooming (Bowling et al. 2018).

Figure 3: Algal bloom in Murry River (2009). (Source: Water NSW 2009)

3. ALGAL BLOOM IN OCEAN WATER

Apart from lakes and rivers, occurrence of algal blooms are also noticed in ocean water as well. Certain environmental conditions allow excessive growth of phytoplankton, which create very dense clouds of algal blooms and change the colour of ocean water. Integrated Ocean Observing System (IOOS) has identified three types of red tides, which are often found in ocean water (IOOS 2018).

- ‘Red tides’ or dinoflagellates are produced by phytoplankton. It mainly consists of peridinin (red pigment), which turns some parts of ocean water color into red. This type of algal bloom commonly seen in the Gulf of Mexico, Florida and South American west and east coast.

- ‘Green tides’ is a photosynthetic and unicellular algal bloom, caused by phaeocystis and macroalgae. The presence of green tides increase the demand of oxygen demand in water, which causes eventual death of and marine fisheries due to lack of oxygen. This types of bloom can be seen worldwide.

- ‘Brown tides’ can be produced by pelagophytes. This type of algal bloom is more often observed in the mid-Atlantic and northeast United States estuaries.

4. EUTROPHICATION MODELING

3.1 Effect of drought

Due to climate change and rainfall variability, the incidence of drought in many parts of the world has been increasing in frequency and severity. During droughts, the climate water deficit spreads through the hydrological cycle and can then reduce groundwater, streams and lake levels. This is often referred to as a hydrological drought which indicates that these effects can be spatially and temporarily separated from the climate drivers of drought. Hydrological droughts can also lead to major changes in the quality of water. In the last few years, several observational studies have been conducted at local and regional scales on the impacts of drought on water quality in Australia. Many lake and reservoir systems will likely be affected in the same way. Augmented extraction of water for consumption also increases the probability of hydrological droughts, irrespective of changing climatic factors. The forecasts of an increase in the frequency and severity of droughts in freshwater systems and a review and synthesis of the relevant literature on this topic was considered beneficial for this purpose. In general, droughts and the immediate recovery period have had profound effects on water quality. These effects varied depending on the water body characteristics and the catchment (Mosley 2015).

3.2 Impact of anthropogenic nutrients

The eutrophication of lakes has been widely recognized as a global challenge and associated with excessive anthropogenic nutrients (mainly N and P). The increasing anthropogenic discharge of nutrients is the primary cause of eutrophication for a long time. Therefore, for effective management of lake eutrophication, it is essential to determine which nutrient (N or P) should be the priority for control and whether it will change and, if so, what will drive temporal variations. Whether the N or P limitation is dominant in the system depends on changes in lake nutrient dynamics (i.e. cycling in N and P) and hydrological conditions. In addition, the role of N and P in controlling eutrophication varies dynamically throughout the year. In view of the effect of N and P limitations on the growth of phytoplankton, great efforts have been made to reduce external sources of N and P (in particular P). Some lakes responded quickly to these reductions but there was often a delay in other lakes. The internal cycling processes contributed to the change of N and P in the water column more than external loading. Further insights into the nutrient limitation analysis showed that the P limitation was determined by the sediment exchange. Allowing the denitrification contribution to N removal, N was the most frequently limiting nutrient, but P was the most important nutrient for eutrophication management (Wu et al. 2017).

One of the major environmental issues today is the eutrophication of coastal areas and freshwaters. Many parts of the world have been affected by this phenomenon. Eutrophication is usually caused by excess nutrients, mainly N and/or phosphorus P, which are supplied to river systems and ultimately to coastal areas. The development of micro or macroalgal blooms is a major manifestation of eutrophication. In river systems, blooms can cause problems in the production of drinking water. The accumulation of organic matter can also affect water clarity and submerged vegetation to decline and cause hypoxia or anoxia in estuaries or coastal areas. Eutrophication can also lead to harmful blooms of toxic algae. The large delivery of N affects the growth of planktonic organisms and can exacerbate the occurrence of harmful algal blooms (HABs) which can be detrimental for shellfish fisheries, an important economic resource for the region (Passy 2016). Nitrogen (N) emissions from anthropogenic sources enrich marine waters and encourage the growth of plankton. This newly synthesized organic carbon is eventually exported to benthic waters where aerobic breathing causes dissolved oxygen (DO) to be consumed by heterotrophic bacteria (Cosme 2015).

Eutrophication (especially for anthropogenic input of nitrogen) was identified as the main factor in controlling the events of Ulva's green tide. Ulva proliferation was modelled by combining hydrodynamic and biological models with a two-dimensional model (coined 'MARS-Ulves') for five sites along the Brittany coastline (La Fresnaye Bay, Saint-Brieuc Bay, Lannion Bay, Guissény Bay and Douarnenez Bay). The calibration of the biological model was based primarily on the seasonal variation of the maximum nitrogen absorption rate (VmaxN) and the nitrogen half-saturation constant (KN) to reproduce the in-situ measured internal nutrient quotas for each site. Results showed that the nitrate concentrations in rivers must be limited to between 5 and 15 mg/L, depending on the bay, to reduce Ulva biomass by half on the coasts (Perrot 2014).

3.3 Control Mechanism

Water resource managers routinely use a variety of strategies to minimize the effects of cultural eutrophication, including (1) diversion of excess nutrients (Edmondson 1970), (2) altering nutrient ratios (Downing et al. 2001), (3) physical mixing (Huisman et al. 2004), (4) shading water bodies with opaque liners or water-based stains, and (5) application of potent algaecides and herbicides (Boyd and Tucker 1998). Generally, these strategies have proved ineffective, costly and/or impractical, particularly for large, complex ecosystems (Edmondson 1970). Water quality can often be improved by reducing inputs of N and/or P into aquatic systems, and there are several well-known examples where nutrient control has greatly improved water clarity. However, nutrient reduction can be difficult and expensive to control (Søndergaard et al. 2003). The use of algaecides, such as copper sulfate, is also effective at reducing HABs temporally (Boyd & Tucker 1998). In addition to harming a variety of non-target aquatic organisms, algaecides are expensive to apply and also these do not control the primary cause of the problem and subsequently pose a risk to humans, livestock and wildlife. Another alternative to improve water quality in nutrient-rich lakes is biomanipulation (Shapiro et al. 1975). Fish-centric biomanipulation effects on water quality are typically short-lived (i.e., weeks to months), most obvious in small, easily-managed systems (i.e., ponds), and impacted by resource availability, namely P and N (Benndorf 1990; Carpenter et al. 1995).

Despite dramatic improvements in water quality due to massive efforts to reduce the enrichment of nutrients (e.g., Clean Water and Safe Drinking Water Acts in the 1970s), cultural eutrophication and related HABs remain the major cause of water pollution in many freshwater and coastal marine ecosystems and are a rapidly growing problem in the developing world (Smith and Schindler 2009).

As demand for freshwater resources is expected to increase in the coming days, protection of water resources has become one of the most pressing environmental issues and is likely to become further more complicated as climate change, invasions of species and pollution further degrade the quality and quantity of water (Schindler 2006). Control and management of cultural eutrophication is a complex problem and requires the collective efforts of scientists, policy makers and citizens to reduce nutrient inputs, develop effective, long-term biomanipulation techniques and to ultimately restore aquatic species (Chislock et al. 2013).

4. CONCLUSION

This paper presents a review of major incidences of algal blooms and its effect as eutrophication in Australian water bodies. The mechanism behind excessive cyanobacterial growth in water bodies are yet to be well-understood. Nitrogen is frequently considered as the limiting nutrient, however, phosphorus is also an important nutrient for eutrophication management. Nutrient emissions from anthropogenic sources also enrich marine waters and encourage the growth of plankton. Studies showed that the nitrate concentrations in rivers must be limited to between 5 and 15 mg/L, depending on the bay, to reduce Ulva biomass by half on the coast. Control and management of cultural eutrophication is a complex problem and requires the collective efforts of scientists, policy makers and citizens to reduce nutrient inputs, develop effective, long-term biomanipulation techniques and to ultimately restore aquatic species.

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Student Engagement in Online Delivery of Courses

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Extended Abstract

There has been a significant drive by universities to include online courses as part of their education systems. At Western Sydney University and many other universities in Australia and around the world, online courses are becoming more and more available. There is also a drive by university administrators to make more subjects in various courses available in the online mode. Statistics show that 3.2 million higher education students in the United States were studying at least one online course in fall of 2005 (Dixson 2010).

One of the challenges for online course instructors is to engage students and keep them motivated (Magna 2012). For the online students themselves, there is a constant battle to remain focused mostly due to the continuous use and increase and popularity of real-time online conversations and discussions. As a result of the difficulty to maintain engagement in online distance courses, experience has shown that attrition in online learning courses is, on average, 10-20% higher than that in traditional courses that use face-to-face contact as a significant means of content delivery (Magna 2012). de Freitas et al (2015, pp. 457) also reports that "there is growing evidence that only a tiny fraction of MOOC's enrolled students completes the courses".

This paper will review some of the methods that can successfully be implemented in online education to improve student engagement and thereby reducing attrition. It will also discuss the methods that can be adopted to evaluate student engagement in online activities. The tools that are commonly used for evaluating online engagement will also be discussed. Some of the methods that will be explored include the use of synchronous activities, teaching presence and mini-videos. Synchronous activities such as online discussions, live chat and online role-play are a form of active learning. These approaches "involve a more discursive and collaborative approach to problem-solving" (McLaughlan & Kirkpatrick 2004 pp.478). Other methods that can be adopted for student engagement include the creation of "online question and answer forums" using various learning management systems (Blicblau 2004 pp.240). One of the advantages of blended learning for example, when compared to online distance learning is that "In the blended learning environment, the digital and face-to-face elements complement each other and are interdependent." (Francis and Shannon 2013). This means that activities which put students and staff in online discussion environments become important in online distance education.

Keywords: Online Learning, Distance Education, Blended Learning.

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Lifestyle, Its Elements and Their Universal Relevance to Wellbeing

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Extended Abstract

Maintaining wellness equates to keeping disease at bay or disease prevention. Yet, the focus of current medical interventions has been on treating disease symptoms, not only because of the urgent need to relieve suffering, but also because of its easily discernible manifestations. However, the underlying cause of ill health often remains after such an intervention, unless the body has been able to deal with it "on its own" in the meantime. The key to body's ability to heal successfully lies in the competency of its immune system to perform its given function – the upkeep of body's self maintenance.

Following the completion of the Human Genome Sequencing Project in 2003 the effect of Epigenetics on gene expression explained the plethora of proteins found in the human body – some six times greater than the number of human genes! The immediate consequence of this realization was the focus on root causes of gene expression – or the whole environs in which genes find themselves. It is this total environmental triggering effect that ultimately constitutes an individual's Lifestyle.

The aim of this talk is to list (and outline) the principal elements of Lifestyle, such that body's ability to maintain itself can be addressed in an organized fashion. This then paves the way principally to disease prevention as well as optimizing one's quality of life. For this to make an impact at an individual's level, requires willingness to take charge of one's own wellbeing as well the passion to do so – rather than leaving it to a health practitioner to deal with the full blown disease symptoms that are otherwise bound to follow.. Going beyond (primarily) an informed individual's responsibility for the upkeep of his/her wellness, is the communal responsibility of care to educate public at large through government initiatives and existing educational institutions, as to what approaches contribute towards maintenance of wellness (or absence of chronic disease!). The ultimate societal health benefits will then follow as well as massive reductions in the government budgetary outlays currently practiced to accommodate the inevitably increasing numbers of victims of essentially preventable chronic diseases.

Keywords: Lifestyle, health, prevention, education

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Lessons Learnt From Modelling End-Of-Pipe Bioretention Systems in MUSIC

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Extended Abstract

This presentation focuses on lessons learned from MUSIC modelling undertaken during planning and concept design stages of a 15 km^2 residential precinct in Western Sydney. A Water Cycle Management study was undertaken during the precinct planning stage, to identify and model the stormwater quality controls. The precinct area was subdivided into sub-catchments and a typical treatment train was proposed for each sub-catchment. The treatment train was comprised of rainwater tanks on residential lots, a Gross Pollutant Trap and an end-of-pipe bioretention system. A MUSIC model was developed during the precinct planning phase to estimate the required bioretention footprints.

The MUSIC models developed during the planning stage needed to be updated since it was developed pre-2011 using a daily time step, and did not comply with recent WSUD technical guidelines developed by the local council. A new MUSIC model was developed during the concept design stage to estimate the required biofilter footprints. The change of time step from daily to 6 minutes and change of rainfall and potential evapotranspiration according to Council's latest MUSIC modelling guidelines resulted in an average 11.5% reduction in TSS, TP and TN removal efficiencies.

It was also proposed during the concept design stage to include a submerged zone within the biofilters, as per current best practice. Therefore, the MUSIC model was updated accordingly. A reduction in TP removal performance was observed when the submerged zone was included. In fact, the outflow TP was found to increase with increasing submerged zone depth, as per the current MUSIC model algorithm (MUSIC Appendix E: Modelling Bioretention System Treatment Performance). However, the latest stormwater biofiltration research indicates a general improvement of TN and TP removal with the inclusion of a submerged zone (Glaister et al., 2014, Payne et al., 2015). Therefore, the TP removal in bioretention with a submerged zone could be a potential improvement in the MUSIC model.

Since end-of-pipe biorientation systems were proposed for the project, the required bioretention footprint was relatively large (> 1000 m^2 on average). During model development for the large systems it was realised that the bioretention overflow weir width is a parameter that can be easily overlooked, but could affect the treatment train effectiveness significantly. Therefore, we believe a warning message/reminder popping up when editing bioretention node could be very useful. Additionally, the current modelling algorithm allows for a linear scale-ability for treatment performance for much larger bioretention areas.

However, in reality the bioretention treatment performance depends on other aspects of constructability and flow distribution and drainage. Therefore, we believe a warning message for larger bioretention nodes highlighting this limitation could be very useful.

We have identified the importance of using a sub-daily timestep and appropriate bioretention overflow weir width in MUSIC modelling and potential improvements for TP removal mechanism in bioretention with a submerged zone.

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Educating Engineers as a Person for the Global Society and Sustainability

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Abstract

The UN Agenda 2030 has set some 17 sustainable development goals (SDG) and 169 targets to be achieved by 2030. With the current world population of 7.7b, rising to an estimated 8.6b by 2030, and with rising globalisation of technology and resources, every world citizen is under stress of a kind, to tackle either a basic survival or a lifestyle race. To reduce inequalities (SDG10) but achieving or sustaining reasonable gross domestic product (GDP) level in every nation, in 21st Century and beyond, will require the world citizen to work smarter, intellectually, physically, ethically and emotionally. This article provides an overview of how personality, society and sustainability are connected then indicates how to design education system for developing engineers as world citizen.

The sustainability race:

It is not quite certain, how the achievements of the sustainable targets are responsibly measured, but sure, the cycle of any impact, if the targets are 100% achieved, will be realised in a very long term. The impacts will be visible in real world climate phenomena, the human lifestyle balance and so on, in many decades from now. Further time expansion, such as Agenda 2050 and Agenda 22C (22nd Century) for similar goals to be set soon.

Good thing is that most corporate businesses, most government bodies, non-government organisations, numerous philanthropes are putting sustainability as one of their activity agenda. The many decades of work since it was first realised that human activities on this planet is responsible for the climate related impact to the life on the earth, the world citizen is now moving forward to recover.

However, the balance between the sustainability and the prosperity is still a dilemma in many nations, specially the fast-developing nations and the developed ones. The concept of sustainability needs to enter the root of all the activities on the planet by every single citizen. To enable this, sustainability education must spread rapidly in all levels of education, from primary through tertiary and any continuing education programs worldwide. The fundamental of the sustainability education is giving the understanding of how everything we do (our act) is connected to the planet and our lifestyle and then inquire into how we also design our work to create a sustainable lifestyle on a sustained planet which has natural limits of resources and climate.

Engineering personality and societal connection in the current world order:

In the current world order, the engineering has become the sector which is the most foundation building block of all living functions on the earth, be it food, clothing, housing, infrastructure, aviation, transport, medical, communication, security, agriculture, mining, energy, data and the growing list as far as space exploration and so on. There is a strong correlation established between GDP growth (an indicator of prosperity) and number of engineering graduates in the most fast-developing countries. Therefore, engineering education remains one of the most fundamental need of this century in addition to the basic education listed in the SDG4.

The economic development requires continuous improvement of engineering concepts and material transformation through creative and innovative exploration of science and techniques. The innovative products or services to support the consumers including those with a certain social, cultural and personal needs. Therefore, it is the need, the personality and the science all three blend together in a lifestyle design, where engineers have a strong role to play and take that as opportunity. In the 21st Century, the engineers will need to develop strong self-esteem and establish personal strengths to take the challenge of one's own choice, thus be able to deliver sustainable lifestyle for the future citizens, without being a passive citizen who considers employability as the prime purpose of becoming an engineer.

Traditionally, the material outcome of an engineering graduate lies in their technical success after the graduation. An engineer, as develops the career as a person and as a professional, can and do influence the people and social culture and lifestyle in addition to the technical success. In this challenging time of 21st Century, the engineering education will need to prepare engineers capable of working locally while learning as well as delivering creative, innovative but socially sensible sustainable engineering solutions as a world citizen. A world citizen is a personality which takes ownership of the progress and concerns of the human society and the earth as single entity and respects other's presence equally on this planet.

To work as world citizen, engineers also need to develop personal traits that help both, the prosperity and sustainability, globally. Engineers will need to develop strong ethical and moral sense which cross national borders. The global connectivity in the recent world order has already demonstrated how cultural and social practices are migrating fast through communication and cross-national people movement. Engineers are no different. Engineers thus need to develop tolerance and be respectful to muli-cultural differences worldwide.

In coming decades, the engineers will need to have strong language adaption and communication skills that fits in multi-cultural environments. They will need strong background of social history of their target choice of nations to serve. They will learn the problems and needs of other society and prepare them to fit for others as well as for their own nation. Engineers will need to design systems with a mindset that the local climate impact and actions (SDG13) have global outcomes.

To balance the prosperity and sustainability, engineers must have a good sense of entrepreneur attitude, delivering project outputs in a team environment collaborating with cross functional personalities in work place as well as co-sharing the concepts of sustainability. It is believed that engineers are not good leaders. To deliver the sustainability globally, this will need to change from being a doer to a leader-doer.

The engineering education:

In order to develop an engineer becoming fit for the challenges of sustainable world, the education system will need to cover technological, spatial and temporal scale of knowledge. The globally diversified educational institutions will take the benefit of global connectivity to really help achieve the sustainable goals on worldwide scale. Every course must contain element of sustainability of relevance to the course. The subject delivery must emphasis a connection between the content and the concepts of sustainability, where it exists. Courses to have open choices of subjects fostering a student centric development rather a degree-oriented development. Student centric development means that student can chose whatever subjects fit in their personality and their choice of the society to serve.

A simple example of how to achieve SDG10 (inequality) is by outsourcing engineering skills beyond national boundaries. This will also close knowledge gap amongst the geographical space as well as improve cross national economic remittance benefits. Particularly, nations which has high population vs useful natural resource ratio, who cannot feed on the local natural resources, the opportunity to outsourcing will dramatically give them opportunity to earn thus to reduce poverty (SDG1) and

hunger (SDG2). To make cross national outsourcing successful, the world needs global engineering education curriculum standardisation and recognition.

Educational institutes will need internationally collaborative quality control in curriculum outcomes through of teaching and research. Engineering education will need active training on creativity development opportunity by inquiring into deep learning and challenging with real world complex problems that the world faces every day. However, it is not that every student will take the same challenge and become equal engineers. It will thus again, derive how a person can become emotionally connected and passionate about making a change in the world. The education system may also impose a professor to have real world engineering outputs for a progressive percentage of time, such as 25% or so, enabling them to develop engineers with real world challenges.

The engineering personality development should be an active education program instead of students learning through passive interaction with other model personalities. Language, communication, cultural and social history learning opportunity will make engineers more productive in delivering the social change that is required for the future sustainable world. Leadership training also should become a curriculum choice for engineers.

The model that is explained above will also help balance the GDP growth globally, assist technology migration complementing people migration, and to improve the urban settlement (SDG11), industrialisation (SDG9) and employability (SDG8) and positively impact all other sustainable development goals.

Keywords: Engineering Education, Society, Sustainability in global scale, World citizenship, Sustainable Development Goals, Engineering personality, Innovation, Global connectivity.

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Sydney Zoo: A Vision for Experimental Learning of Sustainable Water Management

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Abstract

Traditionally, industrial and commercial developments are constructed with the aim of commercial gains but not for achieving educational or sustainable objectives of the public. Universities on the other hand struggle to find an industrial partner who could provide a platform for students learning through experience. This can be a significant "bottleneck" for student learning, especially in engineering. Western Sydney University (WSU) is trying to address this bottleneck in collaboration with Sydney Zoo by promoting a "living lab" concept for student learning. Through this concept students of WSU will be able to see how the theory leant in the class room works in the real world. WSU Water Group is developing key concepts in terms of sustainable water management within Sydney Zoo. Once these key concepts are implemented Sydney Zoo will be able to save significant amounts of water. Also, effectively recycle the water and nutrients within the zoo. This project has multiple aims.

Education to the public and school children is ensured through the establishment of a control room where daily rainfall, amount of water captured, storage levels, estimated evapo-transpiration, evaporation loss and water demand for various uses are displayed. Software is to be designed by computer science students of WSU to display the required information. Weather information such as rainfall, wind and temperature are collected via weather station.

Education and innovative technologies development by the university students are ensured from collected information and projects using real life data from treatment facilities. Simulation and model validation/development from the data collected from weather station and run off measured at various points of zoo catchment. Students specialising in education could also participate in design of various educational strategies. Water saving devices and efficient watering systems will also be tested.

Experimental water treatment units are implemented for car park surface run off, rain water from roof tops and other surface run off and research partnership ensured through these units. Experimental resource recovery is installed closer to the wastewater treatment units for recovering nutrients and energy from the waste. Engineering students with sustainability knowledge will also have an opportunity to test, if these technologies are actually sustainable through application of tools such as life cycle assessment and material balance concepts.

It is expected that this facility will: act as an education/research platform for sustainable water management, energy and nutrient recovery; demonstrate successful university-industry partnership to produce job-ready engineers and graduates to fuel the economy; and act as a demonstration facility for a suit of sustainable technologies. Overall, the Sydney Zoo will act as a "living lab" for the University students to test their sustainability concepts learnt as part of the course work at WSU.

Keywords: Sydney Zoo, sustainability, water, WSU, living lab