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Eee Loon Tan, Balbir Singh, Surendra Shrestha, Sarah Zhang, Olivia Mirza, Yang Xiang, Ataur Rahman, Eds.

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Welcome by Conference General Chair

The International Conference on Advancements in Engineering Education (iCAEED-2019), aims to provide an international platform for effective exchange of ideas, reaffirming the existing collegial contacts, provide opportunities for establishing new ones as well as providing a forum for academics and researchers to present and share the results and findings of their latest research and practice on a wide range of topics relevant to engineering education.

I would also like to thank Professor Barney Glover, Vice-Chancellor and President, Western Sydney University for his kind support towards this congress. I would also like to thank Professor Simeon Simoff, Dean, School of Computing, Engineering and Mathematics, and Professor Yang Xiang, Interim Dean (Planning), School of Engineering for their kind support and encouragement to make this congress successful.

As the General Chair of the 2nd International Conference on Advancements in Engineering Education (iCAEED-2019), I would like to thank the Plenary Speakers, Keynote Speakers, Invited Speakers, Authors, Sponsors, Secretaries, IT Team Members, Conference Advisory Committee Members, Organising Committee Members, Technical Committee Members, Reviewers and Volunteers for making this conference successful.

Professor Ataur Rahman, PhD, FIE Aust, MASCE, MAGU, MIWA
General Chair
2nd International Conference on Advancements in Engineering Education (iCAEED-2019)

Welcome by Conference Chair

On behalf of the Organising Committee, I am very pleased to welcome you to the 2nd International Conference on Advancements in Engineering Education (iCAEED-2019) at the beautiful Parramatta South campus of Western Sydney University.

Engineering profession in the world is facing a challenging time in the coming years as engineers will need to play a key part in addressing problems from climate change and technology advancements and finding solutions for sustainable development of our society. This conference provides us a great opportunity to think about how we should educate our students to become future engineers who have in-depth technical knowledge, social intelligence and creative capacities to make great contributions in addressing the 14 NAE grand engineering challenges (http://www.engineeringchallenges.org/) and the 17 UN sustainable development goals (https://sustainabledevelopment.un.org/?menu=1300). Recently, the Australian Council of Engineering Deans has published a report "Engineering Futures 2035" (http://www.aced.edu.au/downloads/Engineering%20Futures%202035_Stage%201%20report%20for%20ACED_May_16_2019.pdf) which has explored possible solutions for training future engineers to meet our society needs.

I would also like to take this opportunity to thank our conference participants, sponsors, Organising Committee and Technical Committee members and student volunteers to make our conference a great success!

Professor Yang Xiang, PhD
Chair
2nd International Conference on Advancements in Engineering Education (iCAEED-2019)

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PLENARY SPEAKER

Dr Marlene Kanga AM, Hon. FIEAust, Hon. FIChemE, FTSE

Topic: Advanced technologies to Engineer a Better Sustainable World

Biography: Dr. Marlene Kanga is President of the World Federation of Engineering Organisations (WFEO), the peak body for engineering institutions internationally representing some 100 engineering institutions and approximately 30 million engineers. She led the proposal to declare 4th March every year as World Engineering Day, the first Day will be celebrated on 4th March 2020. She is the 2018 Engineers Australia Professional Engineer of the Year. She has been listed among the Top 10 Women Engineers in Australia, the Top 100 Women of Influence and the Top 100 Engineers in Australia. She is a Member of the Order of Australia, a national honour, as recognition of her leadership of the engineering profession. Dr. Kanga was National President of Engineers Australia in 2013. She is a board member of Sydney Water Corporation, Australia's largest utility, AirServices Australia with responsibility for Australia's air navigation services and a member of other boards involving innovation. Dr. Kanga is a Chemical Engineer and a Fellow of the Academy of Technology Science and Engineering (Australia), a Foreign Fellow of the ASEAN Academy of Engineering and Technology. She is an Honorary Fellow of the Institution of Engineers Australia and an Honorary Fellow of the Institution of Chemical Engineers (UK).

KEYNOTE SPEAKER

Professor Roger Hadgraft, Director, Educational Innovation, Faculty of Engineering and Information Technology, University of Technology Sydney, Australia

Topic: Engineering Education in Australia: Current Trends

Biography: Roger Hadgraft is a civil engineer with more than 25 years of experience in improving engineering education through problem- and project-based learning (PBL). He was instrumental in introducing a project-based curriculum in civil engineering at Monash University and in several disciplines at the Royal Melbourne Institute of Technology (RMIT). Roger was an Australian Learning and Teaching Council Discipline Scholar and co-author of the Threshold Learning Outcomes for Engineering and Information Technology and he has been a member of several national learning and teaching projects. He is currently Director of Educational Innovation at the University of Technology Sydney with a focus on curriculum transformation towards 21st century skills.

KEYNOTE SPEAKER

Professor David Lowe, Deputy Dean, Faculty of Engineering
The University Sydney, Australia
Topic: Augmenting laboratories: improved linking of theory and reality

Biography: Professor David Lowe is Deputy Dean and Professor of Software Engineering in the Faculty of Engineering at the University of Sydney. He was also previously the CEO of the not-for-profit organisation The Lab Share Institute and past president of the Global Online Laboratory Consortium. He started his career in industry as a control system engineer but has subsequently ranged across fields as diverse as computer vision, software engineering, web development and real-time systems. He currently has active research interests in laboratory education and professional practice. He has published widely, including three textbooks. David is also passionate about supporting student learning, educational innovation and promoting interest in STEM careers.

KEYNOTE SPEAKER

Professor Muhammed Alamgir, Member, University Grants Commission of Bangladesh, Bangladesh

Topic: Engineering Education in Bangladesh at Postgraduate Level

Biography: Muhammed Alamgir, presently a Member at the University Grants Commission of Bangladesh, is a Professor of Civil Engineering at Khulna University of Engineering & Technology (KUET) since 2002, where he joined as a Lecturer in 1986. He was the former Vice-Chancellor of KUET for 8 years from 2010 to 2018. He obtained B.Sc. Engg. (1986) & M.Sc. Engg. (1989) degrees from BUET, Dhaka and Ph.D. (1996) from Saga University, Japan. He was awarded JSPS Post-Doctoral Fellowship (1986-1998), NST Senior Fellowship for 1998-2000. His research areas cover Solid Waste & Faecal Sludge Management, Geotechnical & Geo-environmental Engineering problems and Climate Change Issues. He successfully completed several research projects funded by the Government of Bangladesh and European Commission. He is credited with 244 technical papers published in conference & journal proceedings. He edited two book and six International Conference proceedings. So far 24 students successfully completed post-graduate thesis under his direct supervision including 2 Ph.D. He is the Founder & Editor in Chief of the International Journal of Engineering Science published from KUET since 2010.

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Abstract/ Extended Abstracts

Implementation of Student-focused Pedagogical Approach for Improving Engineering Student Satisfaction

Xiaoshan Lin
School of Engineering
RMIT University
Melbourne, Australia
susanna.lin@rmit.edu.au

***Abstract*—Student satisfaction has become an important indication of teaching quality, as it could influence the student motivation and their academic success. Construction Engineering is a first-year introductory course for Civil Engineering at RMIT University. It forms a solid basis for other core courses in Civil Engineering. To successfully deliver this course, a couple of challenges need to be considered in the curriculum design, including the large class size, the first-year engineering students and the informative course content. This paper presents a student-focused pedagogical approach employed in this course, which takes into account the course delivery method, industry involvement and assessments and feedback. The effectiveness of this approach is assessed by the course experience survey where student satisfaction can be well reflected by answering survey questions. The results have demonstrated a significant improvement in student satisfaction after applying the student-focused approach.**

Keywords—Civil Engineering student, student satisfaction, student-focused approach, course experience survey

I. Introduction

In the context of higher education, student satisfaction is an important intermediate outcome that influences the student's level of motivation which is a psychological factor in academic success, as well as a good predictor of retention. Student satisfaction can be affected by various factors, such as student characteristics, interaction and communication with teaching staff, curriculum design and instruction, and academic services, resources and facilities [1]. The course experience survey (CES) is an effective measure of student satisfaction, which has been used as a principal course evaluation method by many universities in Australia. In this paper, a student-focused pedagogical approach is applied in the development of a first-year Civil Engineering course – Construction Engineering, and the CES results for this course in the past two years are analysed.

The Bachelor of Civil Engineering at RMIT University consists of 4 years of study. As a first-year core course of the program curriculum, Construction Engineering forms a solid basis for other courses in Civil Engineering, such as Concrete Structures, Steel Structures and Geotechnical Engineering. There are three main challenges in the delivery of this key unit to the fresh first-year engineering students: a) large classes (student number > 100) are much more difficult to engage students compared to small classes; b) first-year students usually find themselves in a transitioning period; and c) as an introductory course for Civil Engineering, various topics related to different sub-areas are included. This course is developed based on a student-focused learning and teaching approach, which takes into account effective engagement as well as the needs for industrial input and timely feedback.

II. Curriculum Design Principles

The curriculum development of this course aims to encourage students to realise their full learning potential, and at the same time, to enhance first-year transition in higher education. Three major aspects are considered and discussed in the following sections.

A. Course Delivery Methods

In this course, various course delivery methods are applied, aiming to improve student engagement and satisfaction.

Lectures As Construction Engineering is a core course, the number of students enrolled in the course is normally around 200. With such a large class, traditional teaching via lectures cannot effectively engage students, as the interactions between students and instructors is generally reduced. In this course, large class lectures are designed to provide background knowledge and fundamental theories, and they are supported by other course delivery methods, as discussed in the following paragraphs.

Tutorials It has been reported that memory and learning are assisted by active thinking and problem-solving activities rather than information giving, such as lectures [2]. In this course, tutorial classes with small student groups are developed, and served as a supplement to the large class lectures. More practical and problem-based knowledge are discussed in tutorials. The aim is to encourage effective communications among students and between students and the instructor. The smaller size tutorials would also allow the instructor to provide personalised feedback to students, leading to enhanced motivation of study.

Labs The design and construction practice is heavily dependent on structural concept and knowledge of materials.

As a first-year introductory course in Civil Engineering, Construction Engineering is designed to introduce basic principles and construction practices to students. The lab practice designed for this course is in alliance with the tutorials. The theories discussed in tutorials are applied in the material design calculations and analysis for laboratory testing. This process would assist students to develop a deep understanding through application of knowledge in solving real engineering problems. Also, the team lab work could develop student's communication skill, collaborative skill, time management skill and leadership.

Videos Videos enable students to watch graphic and practical applications of different construction techniques in civil infrastructures as well as design concepts introduced in class, which could not only enhance student's interest and motivation, but also strengthen the knowledge. In this course, two types of videos are prepared for students. Short narrative videos are provided to show the operation of equipment and construction techniques and processes. Interactive videos are used to provide tasks for students to complete.

B. Industry Involvement

With the rapid advancements in construction technologies, higher education has been important for producing professionals who can meet the challenges of the modern construction industry. In this course, professionals in industry are invited to give lectures. The guest speakers can provide students with practical knowledge to solve real-world problems, and at the same time, students could learn the current state of the construction industry and the potential career paths from the guest lectures. In addition, site visits are also organised, such as the visit to the metro tunnel project in Melbourne, which is optional for students and is not included in the course assessments.

C. Assessments and Feedback

Providing feedback to students is essential for effective learning. Regular assessment combined with effective feedback will help students work more efficiently. In this course, the students' performances are partly assessed by final exam in the end of the semester. A fraction of the course (around 50%) relates to laboratories and mid-semester test. To enhance collegiate quality, the assessments are designed to engage students in the whole learning process, and include independent learning and collaborative learning, problem and project-based team work and peer learning. Feedback is provided through various learning tasks, such as tutorial exercise, lab practice, tests and videos for self-study. Through active discussions and teamwork in tutorials and labs, students could receive feedback from both instructor and peers on individual basis. In addition to the verbal feedback, written feedback is provided for the students' lab reports. Furthermore, online tests and self-learning videos are designed to provide immediate feedback for students.

In addition to the feedback provided through learning tasks, weekly consultation is setup to give students supplementary face-to-face feedback. Moreover, an online discussion section is created, which allows both instructor and students to have interactive communication.

III. RESULTS AND DISCUSSION

The results of course experience survey of this course in 2017 and 2018 are analysed in this section. It shall be noted that the aforementioned student-focused approach was not applied in 2017. The information from the survey can be used as an indicator of performance and to improve learning and teaching [3]. Seven basic questions (Q1 to Q7) are included in the CES as listed in Table 1. Two additional questions, i.e. Q8 and Q9 in Table 1, have been added in the survey for this course in 2018. The students' responses are scaled from 1 (Strongly Disagree) to 5 (Strongly Agree), and the CES results in 2017 and 2018 are shown in Figs. 1 and 2.

TABLE I. COURSE EXPERIENCE SURVEY QUESTIONS

Question number	Question description
Q1	The teaching staff are extremely good at explaining things.
Q2	The teaching staff normally give me helpful feedback on how I am going in this course.
Q3	The teaching staff in this course motivate me to do my best work.
Q4	The teaching staff work hard to make this course interesting.
Q5	The staff make a real effort to understand difficulties I might be having with my work.
Q6	The staff put a lot of time into commenting on my work.
Q7	Overall, I am satisfied with the quality of this course.
Q8	I have learned something in this course which has better prepared me for employment.
Q9	Online facilities, such as the course Canvas, are well utilised to enhance my learning experience.

In 2017, 79 out of 167 (47.3%) students completed the CES for this course, and 99 out of 211 (46.9%) students did the CES in 2018. Both response rates are considered to be reliable. Fig. 1 shows the percentage agree for survey questions, which is the number of students who "agree" or "strongly agree" as a percentage of the number of students who respond to that question. As can be seen, in 2017, the percentage agree varied from 57% to 67%. The relatively low percentage agree might be due to the lack of the student-focused approach in teaching practice. Traditional methods were mainly adopted by the instructors in the delivery of course, and the interaction and effective communication with students in class seemed to be insufficient. Some comments received from the students included "There is too much information in the lecture slides and it can get boring really quick." and "Hard to stay concentrated watching 40 minute videos.". Although various assessment tasks were arranged, the provided feedback was not fully satisfied by the students, as evidenced by the comment "There must be more feedback given to students regarding marks and assessment."

In 2018, to improve the CES results, the course was refined, and the student-focused approach introduced in Section 2 was applied. It can be seen from Fig. 1 that the percentage agree for Q1 to Q7 increased significantly with the majority items above 80% in 2018. As for the added questions Q8 and Q9, both received percentage agree of above 90%. Most students were satisfied with the course content, the delivery format and the efforts made by the instructors. Some detailed feedback from students include "All teachers were extremely helpful and felt like they really cared about both the subject material and the students.", "Assessments are clear, and we know what is expected of us. Additionally, the guest speakers make lectures more interesting." and "The content of this course is very interesting and relevant to going to work in the industry."

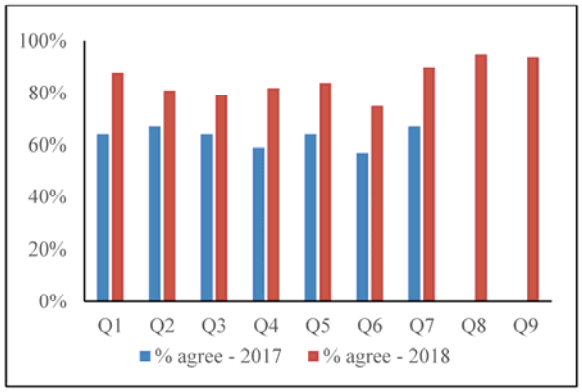

Fig. 1. Percentage agree for survey questions.

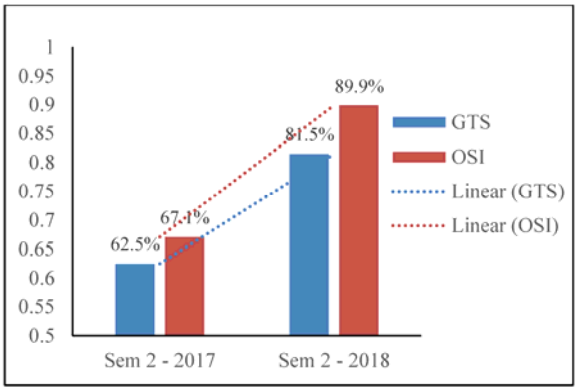

Fig. 2. GTS scores for the instructor in 2017 and 2018.

Additionally, the good teaching scale (GTS) is the measure of students' perceptions of teaching standards in terms of teachers' feedback, motivation, attention, understanding of problems and skill in explaining concepts. The GTS score represents the overall percent agree for the GTS questions. Fig. 2 shows the GTS scores for the instructor of this course in 2017 and 2018. It can be seen that the GTS score jumped from 62.5% to 81.5%, meaning that the number of students who satisfied with the quality of teaching had increased significantly in 2018. Also, the overall satisfaction item (OSI) shown in Fig. 3 has increased by 34% from 67.1% to 89.9%.

IV. Conclusions

To achieve academic success and high student retention, it is important that the students are satisfied with the courses offered by university. Construction Engineering is a first-year core course in Civil Engineering. In order to improve the student satisfaction of this course, a student-focused pedagogical approach was employed in 2018. In the curriculum design, three major aspects are considered, which includes course delivery methods, industry involvement and assessments and feedback. The design of course content and the format of course delivery aim to engage students as much as possible, and at the same time assist first-year students to have a smooth transition to tertiary education. The CES results for 2017 and 2018 are also compared in this study. It shows that the student satisfaction has been improved significantly in 2018 after applying the student-focused method. In addition, numerous positive feedbacks have also been received from the students.

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Civil Engineering Curriculum Reform: Balance among Employability, Innovation and Academic View

Jing LI,
School of Civil Engineering and Transportation,
South China University of Technology
Guangzhou, China
cvjingli@scut.edu.cn

Jing JI
School of Civil Engineering and Transportation,
South China University of Technology
Guangzhou, China
cvjingji@scut.edu.cn

Abstract—Development of employability skill is one of the essential concerns for today's higher education as our graduates compete for jobs with the students from the world. At the same time, innovation ability is becoming a necessary ability for students to survive in the future. However, the academic view cannot be neglected as almost half of the graduates will continue their study to achieve a higher research degree. This paper will explore the trial of civil engineering curriculum reform to balance these three concerns in the Department of Civil Engineering in the South China University of Technology. It discusses five ways applied in this reform, which includes practical courses cooperated with industry partners, problem-based learning workshop, innovative practice opportunity, international cooperation, and common courses for undergraduates and graduated students. The positive response received from the students has proved the effectiveness of the reform.

keyword—employability skill, higher degree, civil engineering , curriculum reform

I. INTRODUCTION

The civil engineering curriculum in South China University of Technology (SCUT), as a research-intensive university, helps the student build up a strong foundation in science, mathematics, mechanics and other knowledge associated with civil engineering. Although the job market for civil engineering is prosperous in China, the graduates need to compete for jobs with candidates not only from the universities in China but also those from other countries, such as UK and USA[1]. Therefore, employability training is an essential concern for higher education.

The world changes fast. New technologies such as 3D printing, robot construction, etc., cannot be taught even five years ago. The innovation is the real ability that could be used by the students for all the life.

On the other hand, half of the graduates today will continue their study for Master or PhD degree. They hope some courses for undergraduates can be designed as a part of the Master course. Then they can use less time to finish their study.

All the three concerns mentioned above are basing on the investigation of our students, their family members, employers and peers from other universities. For balancing these three concerns which look like in the opposite views, the Department of Civil Engineering has tried five ways. After several years of trial, positive responses have been received from all stakeholders, which proves that the measures are effective.

II. MEASURES TO BALANCE THE CONCERNS

Practical courses cooperated with industry partners, problem-based learning workshop, innovative practice opportunity, international cooperation, as well as common courses for undergraduates and graduated students are the measures set for balance the concerns.

A. Practical Courses Cooperated with Industry Partners

Since 2010, Chinese Education Department had the regard on the employability of engineering students and launched a program called "excellent engineers plan"[2]. It means that more practical courses are introduced to the students involved in this plan in the hope that they can have much better employability.

The Department of Civil Engineering in SCUT joined this plan in 2010. Three changes are made for resolving this concern.

The one-week industry study tour is arranged for the first-year students. For the freshmen, this one-week study tour in the industry helps them know what they could do, what they should do, and the responsibilities they need to take after they graduate. During the tour, the students stay in the company, and observe the daily work of engineers. Many students have reported that the most impressive thing is the sense of responsibility of engineers.

One-week industry study tour outside mainland China is arranged for the second-year students. After two years' study, students have already gained the basic knowledge of Civil Engineering. They have a sound understanding of the industry state in mainland China or Guangdong Province during the past two years. The chance for them to find out the differences in the industry in different regions of the world is precious and vital. The students can visit the famous structural consultancies, such as ARUP, and the construction sites under the overseas construction management system.

Five-week internship in construction companies is arranged for the third-year students. The students should stay on the construction site and work with the engineers together. They trained for a lot of abilities, such as communication with different partners. Therefore, the employability is improved through this internship.

For better achievement, close cooperation between the university and the industry partner is necessary. The first thing is to choose the appropriate industry partner. The company should be influential in the industry. It should also have some big construction sites, which can accept our students for internship. At the same time, a good sense of social responsibility is required for the company to ensure the quality of the student training. The second thing is to choose the appropriate construction site. The site should be in a proper construction state for student internship. It is better to involve more construction steps so that the students can learn more on site. Safety and ability to provide accommodation are another two concerns when selecting a construction site. The third thing is to develop a detailed internship plan with the training schedule and proper practice supervisors.

A construction practice for a five-week internship is shown here as an example.

- The site briefing, safety requirement;
- Site explorer;
- Safety visual experience;
- Laboratory, mixing plant visit;
- Quality control seminar;
- Check test for the materials, such as reinforcement sleeve joint, reinforcement, cement, sand, stone;
- Test for maintaining and strength of mortar, concrete;
- Study the positioning method of formwork, the control of axis and elevation;
- Study of the application of integrated BIM for design-construction-maintains;
- Check the reinforcement;
- Study the preparation method of reinforcement, fabrication of steel bar, reinforcement connection and replacement;
- Study of prefabricated construction;
- Study the accurate schedule management based on unmanned aerial vehicle, 3D scanning and BIM;
- Experience of intelligent seatbelt and safety cap;
- Study of formwork and layout of scaffold for exterior wall;
- Concrete supply and casting;
- Casting method of mass concrete and treatment of temperature stress problem;
- Application of RFID technology;

- The layout of vertical transport machinery and arrangement of horizontal transport on Floor;
- Introduction to the design strategy of green campus with BIM technology in the whole process of assembled components;
- Study on tendering and bidding;
- Selection and design of supporting structures for foundation pit;
- Study on construction of foundation and construction technology of full rotary sleeve binding pile;
- One to one to introduce the three-machine linkage grooving technology for diaphragm wall;
- Lifting technology of reinforcement cage for overweight and overlong diaphragm wall;
- Study on cost;
- The technology of base rock grouting;
- Automatic all-weather monitoring and flow-water construction organization of metro tunnels;
- Introduction of concrete and formwork engineering;
- Infrastructure seepage control technology.

Final year projects are supervised by industry engineers. Some of the projects are from the real projects of the engineers. Sometimes new problems are encountered by the engineers during their work. It is a good chance for the students to study these problems and try to conquer them. Through this process, the students can learn how to solve new problems and develop responsibility.

B. Problem-based Learning Workshop

Two kinds of problem-based learning workshop, i.e. the real problem and the virtual problem, are organized. A charity program cooperated with the University of Hong Kong named Mingde program is found for the charity of elementary school in Guangxi Province, which has many far and poor towns. The program members will check the old classroom buildings to decide on whether they need to be rebuilt or repaired. The students will conduct the survey, do the feasibility study, design the building and participate in part of the construction work. In this workshop, the students will contribute to each step of the building design and construction. As it is a charity program, nobody will get paid for the program, and all the costs are covered by donations. The social responsibility is developed from this program. Another workshop is based on a virtual problem. Usually, the virtual problem is at the leading edge of technology development. Several examples of virtual problems are as follows.

- The application of unmanned aerial vehicle in the construction field. The workshop will investigate the technology of 3D mapping, environmental sensor and thermal imagine camera, the risk assessment and law factors of unmanned aerial vehicle application.
- The application of XR. The workshop will investigate the diversified visualization means for engineering design via XR (AR, VR, MR), including the design check, project presentation, market promotion and public display.
- The intelligent management system for the building maintain via BIM, BMS and FM. An integrated management platform is built based on BIM, connected with the other relative management system with BMS and FM to provide a beautiful interface intuitive, simple and convenient operation.

C. Innovative Practice Opportunity

Two kinds of innovative practice opportunities are provided for students. One is for entrepreneurial development. Alumni are invited to give seminars to introduce how they started their business and how they conquered the difficulties. Students are encouraged to join the entrepreneurial competitions to develop their capacities. The other is for innovative ability. Students are encouraged to propose their own research ideas. If their research ideas are assessed to be feasible, supervisors and funding are provided for them. Half of the students will join this kind of research.

D. International Cooperation

To improve international employability, international cooperation is strengthened. Firstly, the second-year study tour outside the mainland China is the first time to open the students' horizon; secondly, the summer study tour for the third-year students would provide them the overseas student life experience. As our students are known by the professors of the overseas universities, it will be

easier for them to accept our students as their Master or PhD students; thirdly, overseas professors and engineers are hired as our part-time academics to supervise the final year projects, the entrepreneurial projects and the innovative research projects. At the same time, we have developed various exchange programs with the overseas universities, such as the University of New South Wales and the University of Western Ontario. Overall, the students have more chances to study abroad.

E. Common Courses for Undergraduates and Postgraduates

A set of common courses for undergraduates and postgraduates has been built for the students who will take further study after graduation. If the students complete these courses along with their undergraduate study, they could reduce their postgraduate study load, and they could save more time for further research.

CONCLUSIONS

Through the reform of these years, many changes occurred. More than 30 industry internship bases, including two overseas internship bases, are founded. The syllabus of the problem-based learning workshop is set. Golden awards of national entrepreneurial competitions are achieved. Half of the students have participated in the innovative research projects. All of the students have the opportunities to be a part of international cooperation programs. A quarter of the graduates continue their study overseas. Four common courses for undergraduates and graduates are built.

Industry development leads to more concerns about higher education. The reform of the traditional curriculum is needed due to different requirements of the stakeholder and new challenges. Some trial methods have been tested in the Department of Civil Engineering in the South China University of Technology. Excellent feedback has been received from the graduates, the overseas universities and employers.

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Gender equality in Australian engineering and the recommendation for progressive industrial change to represent and retain women in the industry

Danielle Kirby
Engineers Australia Sydney Women in Engineering Division
Sydney, Australia
daniellekirby1@outlook.com

Olivia Mirza
Engineers Australia Sydney Women in Engineering Division
Engineers Australia Western Sydney Region Group
Sydney, Australia
o.mirza@westernsydney.edu.au

This study uses existing research to discuss gender equality, in both the Australian workplace as a whole and then the engineering industry specifically, to support the recommendation for progressive industrial change. The purpose of this paper is to provide five key areas of focus to enable the industry to commence and then sustain progressive industrial change and therefore retain and represent women at all levels.

Keywords— gender equality, progressive industrial change, retention of women in the workplace, women in engineering, Australian engineering industry

I. Introduction

Gender equality can be defined as "the state of having the same rights, status and opportunities as others, regardless of gender" [28]. One measure of gender equality in the workplace is the balance of male and female representation at all levels [26]. This study uses existing research to demonstrate that, while many Australian industries in the 21st century are achieving a balance in the representation of males and female and hence becoming more gender equal, the engineering industry is not.

This study will focus address the following questions:

- What strategies are currently being used to further represent and retain women in the Australian workplace?
- What strategies are being used to further represent and retain women specifically in the engineering industry?
- Which of these strategies have had a successful impact on gender equality?
- What are the barriers preventing these strategies from achieving progress in gender equality?

By addressing these questions, this study is expecting to develop an innovative approach and to articulate this approach as a recommendation to how gender equality can be progressed in the industry. This recommendation will then be tested through two separate real life and current case studies.

The hypothesis is that ad-hoc strategies are currently in place whereas a more holistic and integrated approach is required to break down the persistent barriers to gender equality in the engineering industry.

II. Gender Equality in the Workplace

The gap between the representation of women and men in the Australian workplace is closing, depicted in Fig 1, however women's representation is still frequently described as a "leaking pipeline" across many professions [10, 24, 29, 33, 34]. Women comprise 47% of employed persons in Australia [1] but are representing only 30.5% of key management personnel, 25.8% of directorships, 17.1% of CEO and 13.7% of chair positions [31]. Australia's Gender Equality Scorecard reports 35.2% of boards and governing bodies have no female directors, compared to 0.9% having no male directors [30].

Looking at the engineering industry specifically, there has been minimal progress in gender equality. Engineers Australia reports the average completion of engineering courses by women has been around 14% since 2013 [20]. Of those qualified with an engineering degree, only 51.2% of women go on to work in the industry with women representing a 12% portion of engineers today [12], a portion which has not progressed in over two decades [8].

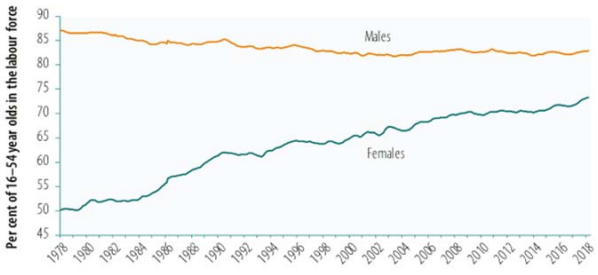

Fig. 1. Australian Labour force participation rate of males and females aged 15 to 64 years [15]

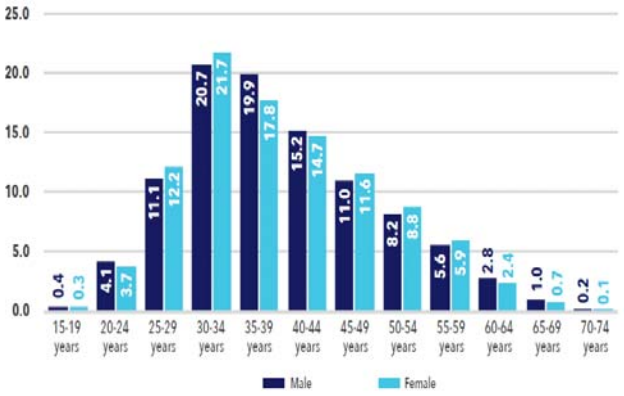

Fig. 2. Gender based workplace responsibility by responsibility level (%) – Engineering [13]

Professionals Australia undertook a survey in 2017 which found the engineering industry is one of the professions experiencing the "leaking pipeline" effect. The findings from this survey are illustrated in Fig 2 with the representation of women decreasing with responsibility. 26% of women who responded to the survey were employed at Level 4 or higher compared to 42% of males [13].

III. Strategies to Increase Gender Equality

There has been a conscious effort to firm up the pipeline of women entering the engineering work force. Master and Metzoff (2017) validate that "innovative practical interventions can increase and equalize motivation and engagement in STEM" [22]. Schools are using this intervention with a conscious effort to deliver Science Technology Engineering and Mathematics (STEM) subjects in a more appealing manner, through creativity and practicality as oppose to theory, with emphasis on breaking the male scientist/engineer stereotype (see Table I). Programs run by various organisations complement these efforts, for example 'Women in Engineering' groups at universities who are "improving the outcomes for women who want to study engineering" [8].

TABLE I. STEM PROGRAMS

Programs Targeting STEM Stereotypes	
Program Name	***Website***
Curious Minds, Australia Science Innovations	www.asi.edu.au
Girls in STEM, Women in Science Australia	www.womeninscienceaust.org
Spark Engineering Camp, Youth Without Borders	www.spark.ywb.com.au
Girls in Engineering, University Western Australia	www.uwa.edu.au
Programs for Schools, Girls Geek Academy	www.girlgeekacademy.com
Day of STEM in Classroom, Life Journey	www.dayofstem.com.au/education
Women in Engineering, Engineers Australia	www.engineersaustralia.com.au
Girls in STEM programs, University of Technology Sydney	www.uts.edu.au
Power of Engineering	www.powerofengineer.org

Pressure is being applied to balance out male dominated workplaces at a politically level. Through Australia's Equal Futures Partnership, the Government has identified "strengthening the pipeline of female talent in traditionally male-dominated industries as an important priority" [6]. This has led to various initiatives including the G20 in 2014 where the goal was set to reduce the gap between male and female participation in the labour force by 20% to 2025 [14]. Within the engineering industry specifically, the Australian Workforce and Productivity Agency (AWPA) provides key recommendations to address gender equality [8]. These have been summarised for this paper into the following four points;

- Targeted gender workplace programs,
- Workplace flexibility,
- Working with education providers, and
- Developing targeted policies.

IV. Barriers to Gender Equality

The barriers to gender equality in male dominated workplaces are well documented. From an early age children are influenced by stereotypes, the most prominent stereotype for engineering being that an engineer is male and works in a hard cap on a construction site. Master and Meltzoff (2017) explain that these stereotypes "create a lower sense of belonging among women than men in certain (STEM) fields" [22], deterring women from studying STEM subjects and limiting the pipeline of women entering the industry. A further barrier was evidenced through a 2017 survey undertaken by Professionals Australia which found women offered a place to study engineering at university have particularly high academic scores (ATARs) compared to men [13], as per Fig. 3.

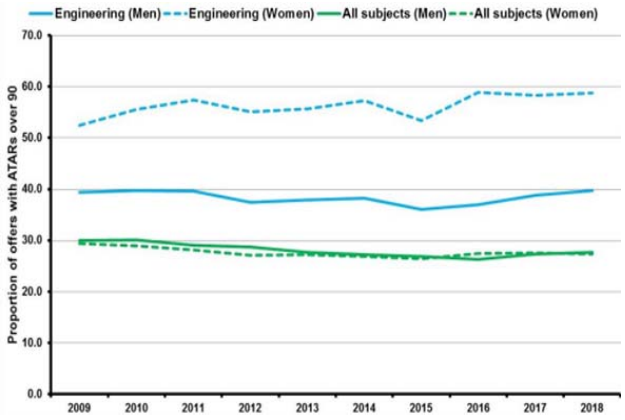

Fig. 3. Offers in engineering - Difference between women and men ATAR [13]

Stereotyping and discrimination extend from school and university to the workplace with AWPA (2014) documenting "subconscious" stereotyping resulting in work being distributed based on gender, for example women being specifically delegated the tasks of taking notes or making coffee [8]. In the 2017 Professionals Australia survey, 48.2% of women respondents reported they had experienced gender discrimination compared to 5.7% of male respondents reporting [13]. The gender pay gap is another quantifiable barrier in industry with female engineers earning a total package of 24% less than their male counterpart [17] with this gap increasing with years of experience [13].

V. Recommendations

Based on the discussion above, this paper recommends that the Australian engineering industry follow a progressive industrial change trajectory to attain gender equality, which would be evident through the representation and retention of women in the industry. The following two definitions to explain progressive industrial change are applied:

- **Industrial change** refers to ongoing economic and social development in all sectors and fields of activities [17, 23].
- **Progressive** systems develop steadily and are "new and modern, encouraging change in society or in the way that things are done" [11].

Drawn from these two definitions and the discussion above, the recommendation for progressive industrial change is supported with five key focus areas:

1. **"Ongoing"** – An industry leader champions the change and is supported by an industry wide framework, creating sustainable and long term initiatives with specific targets and clear accountability.
2. **"In all sectors and fields of activities"** – A holistic, multi-faceted approach is undertaken, guided by the overarching industry framework, where all activities are inter-related and effortlessly encourage gender equality.
3. **"Steady and incrementally"** – The industry works as a system and aligns strategies to where it lies on the change trajectory. The future state for gender equality is continually reviewed and renewed.
4. **"New and modern"** – The industry as a whole finds new ways to realise the benefits of a diverse and inclusive work place which satisfies the needs of the future.
5. **"Encouraging change"** - Change to progress gender equality is not an effort but a journey the industry is encouraged to be on.

Aligning with these five key focus areas and drawing conclusions from the discussion above, this paper describes a generalised current state for the Australian engineering industry as follows;

1. **"Ongoing"** – There is no industry leader driving the way forward and no industry wide framework guiding organisations towards gender equality. Organisations respond to policies or reach a target and then withdraw their efforts.
2. **"In all sectors and fields of activities" –** A holistic approach to gender equality is not taken. Strategies and activities are ad hoc and the drive behind activities is often "person-centred" [27] where women are placed as the issue with the onus on them to adapt and/or change. Women are having the conversations and participating in initiatives around gender equality while men are not.
3. **"Steady and incrementally"** – There is no consolidated, industry wide response that aligns the industry allowing it to progress forward. This has been seen in with the representation of women in the industry remaining relatively stagnant. There is no vision as to what the future state of gender equality looks like for the industry.
4. **"New and modern"** – Organisations in the industry have policies and strategies which are generic and include targets which are viewed as obligatory numbers to reach. Many organisations have a formal policy but no strategies to actually implement these. The benefits of a gender equal workplace are not articulated or recognised industry wide.
5. **"Encouraging change"** – Change is viewed as a burden, resulting in hesitation to the increased cost, efforts and the unknown with some feeling threatened about what the change with a gender equal workplace might mean for their position.

VI. Case Studies

To support the recommendation made by this paper, two case studies where progressive change mechanisms have been used to advance gender equality are provided.

A. Case Study 1 – Australia Post

Australia Post provides postal services in Australia, directly employing 35,000 people [5]. In 2018, Australia Post reported gender pay parity for the second year running, greater representation of women in management and of having appointed the first female CEO [4]. Australia Post has used progressive change mechanisms as follows;

1. **"Ongoing"** – The organisation's then CEO, Ahmed Fahour, drove gender equality stating "the moment we stop focusing on improving gender equality is the moment that we go backwards" [2]. The Gender Action Plan (2015) provides a framework explicitly calling out this "ongoing commitment" with specific targets and accountabilities.
2. **"In all sectors and fields of activities"** – The Gender Action Plan (2015) and Diversity Inclusion Plan (2017) outline how the vision for gender equality will be achieved through activities which span all

fields (operations, finance etc) and seniority levels [2,3]. Further to this, both men and women are actively involved in these activities.

3. **"Steady and incrementally –** Highlighted in the 2018 Annual Report is the "conscious effort to reduce gender inequalities" which has spanned over eight years. Over these eight years, new strategies and initiatives have been implemented to align the organisation on its change trajectory. This has resulted in gender equality progressing forward as evidenced through the representation of women in the executive team growing from 0% in 2010 to 55.6% as of 2018 [4].
4. **"New and modern"** – Benefits are realised beyond just hitting targets, as stated by the then CEO Ahmed Fahour "building gender equality also makes good business sense" [3]. This mentality has resulted in the implementation of innovative programs such as;
    - "ProjectMe", a personal ad career development program,
    - "Elevate", to develop female talent,
    - "Xplore", leadership and career management program, and
    - "TenProgram" a formal mentoring program.
5. **"Encouraging change"** – Championed by the CEO, gender equality is part of the underlying strategy and business model of the organisation (as seen in the 2018 Annual Report). Commitments stated in the Gender Action and Diversity and Inclusion Plans demonstrate willingness to put effort and cost into further progressing gender equality at Australia Post.

B. Case Study 2 – Iceland

Iceland is a European island with a population of approximately 340,000. As of 2019, Iceland is a "frontrunner in the World Economic Forum's Global Gender Gap Index for the ninth year in a row" [32]. To continuously move forward with gender equality, progressive change mechanisms have been utilised by Iceland as follows:

1. **"Ongoing"** – The countries leader, Prime Minister Katrin Jakobsdottir, champions and drives the move towards gender equality stating "we must never think that because of (those) milestones or goals reached, the fight for gender equality is something that we can allow ourselves to put on the backburner" [18].
2. **"In all sectors and fields of activities"** – Generally, stereotyping in Iceland is less prominent with support for "strong women" [21] resulting in less cultural bias in the workplace. Men and women share power with near equal representation in the political domain and a multi-faceted approach is seen with action taken in politics, defended by women human rights advocates and enforced with legislation and quotas.
3. **"Steady and incrementally –** More than 40 years ago, 90% of the women in the country famously went on strike and since this time Iceland has continued to advance gender equality with a clear vision of the future state. Addressing the pay gap is an example of this; The Equal Pay Act dates back to 1961 but it was identified that further progress to reach the future state was needed which resulted in a further step in 2017 which was to enforce equal pay [21].
4. **"New and modern"** – Iceland is leading with "firsts"; the first country to enforce equal pay, to have exclusive paternity leave and to directly elect a female president. Benefits beyond the need to just hit targets are realised, with the two statements below highlighting this;
    - "Gender equality is likely to improve a company's image in the eyes of its customers, and make its workforce a whole lot happier." *Hannes Sigurðsson of the Business Iceland confederation* [19].
    - "The (gender equality) net outcome has been more open discussions, higher productivity, greater job satisfaction, improved decision-making, higher morale, and an all-round far better atmosphere." *Bjarni Bjarnason,Cchief Executive of Reykjavik Energy, parent company of Iceland's largest power provider* [19]
5. **"Encouraging change" –** As per the words of the Prime Minister, **"**We (Iceland) are all a part of the change" [18]. The country is not discouraged by the increased efforts and costs with this change. Enforcing gender pay in one example of this with the legislation receiving much push back due to "increased cost and regulatory burdens on firms and (involved) too much interference in labour market processes" [25].

VII. Conclusion

For the Australian engineering industry to represent and retain women, this paper recommends progression industrial change.

Five key focus areas support this recommendation;

- Ongoing,
- In all sectors and fields of activities,
- Steady and incrementally,
- New and modern, and
- Encouraging change.

These five key focus areas illustrate the need for an industry leader and overarching framework to drive the change towards gender equality. As the peak body for the profession in Australia, Engineers Australia should take the lead and work

with government, employers and educational institutions to define and lead the progressive industrial change.

Information on progressive industrial change is limited so a further recommendation is to better understand and apply this in an Australian context. The engineering industry has the opportunity to take the lead and allow other professions which are experiencing the same problems to follow in progressing gender equality using this change mechanism.

When the engineering industry progresses along the change trajectory towards gender equality, by focusing on the five key areas listed in this paper, the Australian engineering industry will be able to retain and represent women at all levels which has benefits spanning business, commercial and the economy.

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Research-based education for industrial development: Experiences of Kathmandu University in turbine technology

Biraj Singh Thapa
Department of Mechanical Engineering
Kathmandu University
Dhulikhel, Nepal
bst@ku.edu.np

Bhola Thapa
Department of Mechanical Engineering
Kathmandu University
Dhulikhel, Nepal
bhola@ku.edu.np

Ole Gunnar Dahlhaug
Department of Energy and Process Engineering
Norwegian University of Science and Technology
Trondheim, Norway
ole.g.dahlhaug@ntnu.no

Surendra Shrestha
School of Computing, Engineering & Mathematics
Western Sydney University
Australia
s.shrestha@westernsydney.edu.au

***Abstract*—Nepal is a developing country with a literacy rate of 64.7% in 2015, which is a significant rise from 20.6% in 1981. About 10 % of the population have excess to university education in Nepal. Among the total population receiving a university education, those getting engineering education is below 2%. Nepal has the second largest hydropower potential worldwide with less than 2% developed so far. The industrial development in Nepal is very slow due to lack of technical manpower and effective electricity supply. Hence there is a strong correlation in the development of technical education institutes, hydropower development, and development index of Nepal.**

Kathmandu University (KU) was established in 1991 with the vision 'to bringing knowledge and technology to the service of mankind'. It has developed its engineering curricula and teaching methods to address the need and demand of the society, with the international standards. Together with Norwegian University of Science and Technology (NTNU), and other collaborating partners, KU has been conducting research and development activities for developing products and services to meet the specific requirement of hydropower development in the region. In particular, it has been successful to develop and transfer the hydro turbine technology for the sediment-laden projects for industrial applications.

This paper introduces Kathmandu University as the pioneer of engineering and technical education in Nepal. The pedagogical approaches practiced by KU and its impact on the development of research-based engineering education in Nepal is highlighted. Opportunities and challenges of hydropower development in the Himalayan region and roles played by KU-NTNU consortium to develop knowledge and human resources to complement it are discussed. The achievements made by the Turbine Testing Laboratory at KU on design optimization of hydraulic turbines for sediment-laden projects are presented in details. The experiences and future direction of cooperation for commercial application of the knowledge developed are also discussed.

Keywords—Teaching Learning Approach, Engineering Education, Hydropower Development

I. INTRODUCTION

Asia region contributes to the highest growth in energy demand, accounting for 70% of the growth in global energy consumption since 2000. This region holds the highest capacities of both, developed and undeveloped hydropower potential worldwide. It is forecasted that the demand for electrical energy in Nepal will reach 3,600 MW by the year 2027. It is expected that the demand for electricity in India will reach 1000 GW by 2030. Similarly, a high rate of increase in electrical energy demand has been forecasted to other south Asian countries [1]. This surge in energy demand in the local and regional market has boosted the construction of new power plants and renovation of old ones for better efficiency. In Nepal alone, 107 hydropower projects with 2356 MW capacity are under construction; Construction license has been awarded to 206 new projects with 7814 MW capacity and survey license has been awarded to 302 new projects with 18248 MW capacity [2]. Thus, there is a need for technical manpower and competence for the development of large hydropower projects in Nepal.

Asia region suffers from soil erosion due to the relatively young geological formation and heavy precipitation in a short time interval causing floods. In the central Himalaya and Ganges plain, more than 80% of the annual rainfall occurs during the Indian summer monsoon season (May–October) [3]. This causes a drastic increase in sediment concentration in rivers every year. Hence, the hydropower plants in these regions are reported to be severely hit by the erosion of turbine components due to hard sediments and cavitation. Figure 1 shows the undeveloped hydropower potential and sediment deposition for different continents. It is evident that future hydropower developments will occur in Asia and those power plants will be affected by the problems of sediments that are carried along with the flowing water. Figure 2 shows an example of material erosion in the turbine runner due to excessive sediment inflow. Several studies have shown severe effects of such erosion on the performance and life of the turbine with significant financial losses. This has created a need for technological advancements and innovations to prevent erosion of mechanical equipment in sediment-laden projects.

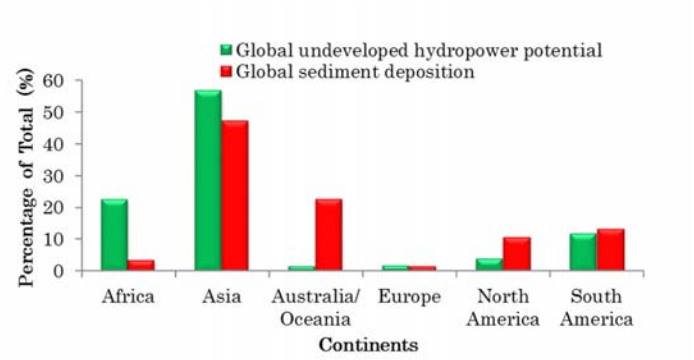

Figure 1. Undeveloped hydropower and sediment deposition [4]

Figure 2. Material erosion of turbine runner due to sediment-laden flow

Most of the turbines installed in Himalayan Hydropower projects are imported from European manufacturers, and most of these turbines are not designed to withstand high sediment loads. Due to low cost, Chinese turbines are more popular in small power plants but have shown poor performance under high sediment load. Thus, there is a need for new turbine design that can have a long lifetime when operated in sediment-laden water.

Until now, Nepal does not have design and manufacturing competence of hydro turbines greater than 300 kW capacities. There are several manufacturing companies in Nepal, which are developing micro-hydro turbines (up to 100 kW). Some of them have the capacity and motivation to manufacture turbines up to 10 MW size, but they lack technical and design competence required for such capacity. Large hydro turbine manufacturers in the west have more than 150 years of technology development. However, they have been specific to the projects with clean water and lack customized design for the local market in the Himalayan region with sediment-laden flows [5]. This has created a knowledge gap for the development of turbines effectively operating in the Himalayan region.

Kathmandu University (KU) is a young but a pioneering academic intuition in Nepal for taking leading steps to offer new and innovative engineering courses to address the current demands of society. KU has practiced several pedagogical methods, which matches to the recent developments in engineering education worldwide [6]. In a short period of 28 years, KU has developed itself as a research-led university with the lessons learned from several hit-and-trail experiences and from the experiences of the established universities as Norwegian University of Science and Technology (NTNU). Engineering education at KU, particularly in hydro turbine technology, has crossed the critical level of research and innovation and has matured to enter the industry sector for commercial applications. The following sections introduce the pedagogical approach practiced by KU and timeline of progressive achievements in its engineering education.

II. Experiences of KATHMNADU UNIVERSITY'S TEACHING LEARNING APPROACH

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Nepal is a developing country with a literacy rate of 64.7% in 2015, which is a significant rise from 20.6% in 1981. About 10 % of the population have excess to university education in Nepal. Among the total population receiving a university education, those getting engineering education is below 2% [7]. A formal university education system in Nepal started in 1959 with the establishment of Tribhuvan University. Nepalese education system during that period was dominated by the Indian system as the higher education in Nepal started with the affiliations from Indian Universities and more dependent on Indian faculties in early days of development. Indian system was also basically influenced by the British system since the time of the British regime in India [8].

KU was established to complement the role of Government of Nepal in higher education after the major political change in the country in 1990. By then, the education programs in Nepal were more teacher-student focused in classrooms and textbook oriented. Very limited practical, laboratory or project-based self-learning flexibility were available. Before KU was established, less than 10% of students were enrolled in technical education sector including Engineering, Agriculture, Forestry and Medicine. The challenge of KU, as the complementary institute was to get established as a new Nepalese university, providing an opportunity to study courses of global attraction, especially in technical areas and offer unique pedagogical techniques to make teaching-learning more effective and interesting for students.

Since its establishment, KU has received very good support from NTNU in the development of curricula, human resources, and research facilities [9]. The major contribution of NTNU to KU is the paradigm shift in the vision of the university education system in Nepal, from the classical classroom-based teaching methods to the research and innovation based learning approach.

At present, KU is leading cutting-edge research in several specialized areas. The quantifiable visibility and impacts have been observed particularly in engineering and medical science studies. Within 28 years of its establishment, KU has practiced following pedagogical techniques in a progressive manner with the lesson learned from each method for the next one.

KU introduced Computer Science course for the first time in the formal education system in Nepal through its Intermediate of Science program started in 1992. The course was featured with more practical and individual ***'Performance Based Learning'***, where each student was evaluated on the basis of performance and progress in continuous assessment basis. This method has been retained as the foundation of KU for the undergraduate and graduate education introduced in later stages.

KU offered its first university-level program in 1993 on Master of Business Administration (MBA). This program was based on ***'Participative Based Learning'***, comprising of presentations, case study, report writing. It was a new form of learning approach started in Nepalese higher education system, which is now practiced in other academic institution as well.

KU introduced 4-years undergraduate program in Science and Engineering in 1994. These programs were based on ***'Project Based Learning'***, with the aim to make student and teacher more interactive to identify the need or problem identification, prepare group work for solving problem, acquire skill and knowledge to solve the problem, develop and test the solution, present and report to the stakeholders for dissemination. The South Asian education system had project work equivalent to 1-2 course work in final semester only. But KU introduced project work in every semester starting from the very first year. This was unique and innovative. It is a concept very close to conventional Problem Based Learning (PBL).

MS by Research program was introduced by KU in 2004 with the aim to produce faculties in specialized area and experts required in the industry. Students are admitted on the merit of their assessment of research problem. University provides an environment to learn the fundamental knowledge and skills to solve the problem and resources and infrastructure to conduct the research activities. The research activities are conducted under the supervision of expert faculties and international journal publications are often expected. The entire program is driven by the passion and dedication of the candidate to get through the research problem with an implementable solution. Hence the program is for very selective candidates and can be as considered as the ***'Passion Based Learning'***. The graduates are successfully performing in the academic sector with research competence, and at the industry with problem-solving capacity.

KU has made several attempts to make a balance between the critical evaluation of research results from specialized labs and practice-based experience in the industries. Engineering profession still uses empirical methods, thumb rules, and evidence-based practices even if engineering science is quite a developed and scientifically verified. Hence the learning based on evidence and adding value to it by research has been a successful practice at KU as the ***'Evidence Based Learning'*** methods. This includes Empirical methods, Experiments, Observational studies, Case studies, Quantitative and qualitative analyses of data, Argumentation analysis, Evidence-based cost estimation, and so on. This method was firstly introduced in 2006 in the field of software engineering. Now it is widely practiced in other disciplines as well.

Geomatics Engineering and Civil Engineering programs at KU were developed in 2009 with a different concept than the regular engineering program. Geomatics Engineering course was launched in the request of Nepal Government to replace the professional training course on senior surveyor offered through Land Management Training Center (LMTC), which was running for almost 30 years. Geomatics Engineering course was aimed to retain the essence of professional training part being offered by LMTC and produce experts at the undergraduate level [10]. Similarly, the Civil Engineering program had the strategy to prepare industry-ready civil engineers to serve Hydropower sector of Nepal. Both Geomatics and Civil Engineering program are the attempts to practice the ***'Profession Based Learning'***. There has been some criticism for preparing specialized graduates at professional engineering level itself instead of providing broader engineering knowledge. But the impact of service by the graduates in these specific profession has supported KU to retain a better position in the academic environment.

With the intentions to reach to the rural communities for bringing the knowledge developed by the university as the solutions to the common problems of the society, in 2010, KU established a project named 'Kathmandu University Community Education Project'. The aim was to integrate the students' project with the rural communities through the university outreach program in the field of education, community development, and business incubation. The program has been further extended within the period of 2013-2016, through a widening scope of activities and geographical areas. The most successful impacts are in the discipline of medical science and hydropower development. The philosophy of ***'Community Based Learning'*** and serving the community has proven to be a way of breaking the walls of the classroom for teaching and learning.

There has been a rapid development in the Information Technology sector in Nepal since 2005. The rise in access to computer and internet among the youths and students have inspired KU to enter and initiate ***'Digital Based Learning'*** era in its education system. E-Learning methods were introduced in 2011 which has changed the means and methods of interaction between the students and faculties [11]. A virtual library is created with the videos of professional teachings in specialized courses and linked with e-learning and open online courses through Moodle systems. In 2016 KU launched MOOC (Massive Open Online Course) in computer programing courses and now it has expanded to several other programs.

KU has 7 schools (Arts, Education, Engineering, Management, Medical Science, Law, and Science) with total students exceeding 10000. KU has been most successful with its engineering programs, which is being offered at its central campus at Dhulikhel without any affiliations or constituent campus. The goal of the school of engineering is to remain small but smart. At present more than 500 students are enrolled each

year under six different programs in the School of Engineering at KU.

III. EVOLUTION OF RESEARCH-BASED ENGINEERING EDUCATION AT KU

KU has played a role model to introduce and establish innovative and unique programs in engineering education in Nepal since 1994. Offering Mechanical, Computer, and Geomatics Engineering degrees for the first time in the country are some of its leadership examples. Integration of academic research with the community and industry are few of its success stories. Within its short span of establishment period, engineering education KU has been able to pass through several stages of the development period, each supplementing the other. The progress and achievements made by KU in its engineering education have been summarized in Table 1.

Table 1: Timeline of the development of engineering education at KU

S.N	Period	Stage	Prioritized activities	Major Achievements
1	1994-1998	Undergraduate Era	Curriculum Infrastructure Human resources Teaching & Projects	Start of Mechanical, Electrical & Electronics, and Computer engineering programs Development of basic laboratories
2	1998-2002	Graduate Era	Master's Program Teaching & Research	Master's program in Mechanical and Electrical Engineering
3	2002-2006	Research Era	Capacity building Research Facilities Joint programs	Training of faculties and staffs abroad Development of research labs International Masters programs
4	2002-2010	Facility creation Era	Specialized labs for advanced research	High Voltage Laboratory Turbine Testing Laboratory
5	2010-2019	Innovation Era	International projects for Industrial research	Renewable Nepal Programme Business Incubation Center Energize Nepal Project FranSed Project

Since the establishment period, KU carried the vision to establish itself as a research-based university. KU has been inspired by the model of NTNU to design its courses and curricula to directly contribute to the research problem the industry or society has been facing. All the engineering faculties are expected to work in some research-based projects funded by the industry or external agency. The students are invited to work under the supervision of the relevant faculties to contribute to the progressive stage of the research projects. The High Voltage Lab and Turbine Testing Labs are few specialized labs at KU built with the technical cooperation of NTNU with major funding from Norway. These labs are the state-of-the-art facilities producing technological advancements through research and innovations, and highly trained human resources for industries. Renewable Nepal programme (2010-2016), supported by the Norwegian Government, was a successful approach to bring the university and industry at a common platform for transforming the knowledge generated through university system to the development of commercial products or services in the industry. A total of 14 projects were funded in the field of renewable energy within 6-year period and 7 spin-off companies were established through the business incubation center, which was a part of the Renewable Nepal programme.

Renewable Nepal projects at KU contributed to the postgraduate engineering programs a KU by supporting the MS by Research students and developing laboratory facilities that facilitate and strengthen the Master program. Later the programme was scaled up as the Energize Nepal Project (2017-2021) to be the largest non-governmental program in the energy sector in Nepal supported by Norway. Major support of this project goes towards supporting industrial-scale research work contributing to the hydropower development in Nepal. Such engagements of KU in managing large scale project to bridge the gaps between industries and academia has brought many direct and spin-off positive effects in the country. In particular, KU has established itself as the pioneer university in contributing to the hydropower development in Nepal and the development of turbine technology for the Himalayan region.

To expand on the successful teaching-research nexus that was developed following the NTNU model (discussed above), KU has begun discussions with Western Sydney University (WSU) to investigate the possibility of developing and implementing a hybrid model practiced at WSU to capture the non-research focused students' interests [12]. The need to develop classrooms as collaborative learning spaces using state-of-the-art technologies to effectively implement the hybrid model is proposed and practiced at WSU [13]. KU is taking a lead role in Nepal to develop and implement these learning and teaching pedagogies.

IV. KNOWLEDGE TRANSFER IN TURBINE TECHNOLOGY

Turbine Testing Laboratory (TTL), inaugurated in 2011, has played a critical role in the School of Engineering at KU for bringing the knowledge and technology for the industrial applications. The main aim of TTL has been to develop and implement the design methods for hydraulic turbines operating

in the sediment-laden flows. The bigger turbines manufacturers are specialized in producing machines for clean water, which are not suitable for this part of the world. KU and NTNU have a joint team working in the field of sediment erosion in hydraulic turbines since 2002. Five academics from KU have completed PhD from NTNU in this specific research area. At present there are more than 11 researchers working dedicatedly at TTL and more than 50 joint articles are published in international journals by KU-NTNU team in this field of studies. The team has produced knowledge for the design and optimization of Francis turbines for sediment-laden flows and developed methods and tools for customized design for specific power plants [14]. The infrastructure, human resources, technical knowledge, and design competence has been developed at TTL in a parallel manner. The role of NTNU and Norway has been pivoting support for such a rapid development of TTL.

At present, TTL is designing one each Pelton and Francis turbines to be manufactured in Nepal for the small scale hydropower projects. Nepalese industry lacks the experience of turbine manufacturing larger than 300 kW capacity. TTL has been supporting and motivating the local turbine manufacturers to prepare for 10 MW size with the existing facilities. TTL carries the vision to support the manufacturers in Nepal to scale up the facilities and competence for manufacturing of hydro turbine up to 25 MW capacity. Several partnership models have been proposed and implemented at KU to support the local industry with the knowledge gained at the university. The model practiced by TTL to interlink the government, academia, and industry through its center of excellence for transferring turbine technology to the industry is shown in Figure 3.

The fundamental objective of a university to create knowledge and technology for the service of society by producing competent graduates has been the primary business of KU. The transfer of knowledge from university to industries has been practiced through the 'Business Incubation Center (BIC)' under the structure of KU. BIC provides a framework for KU to participate actively in strengthening industry and business in Nepal without interfering the integrity of the university. Out of 11 spin-off companies established under BIC framework, 'Turbine Design Services (TDS)' is the one working in a commercial manner to transfer the knowledge and technology to the developed at TTL to the hydropower sector.

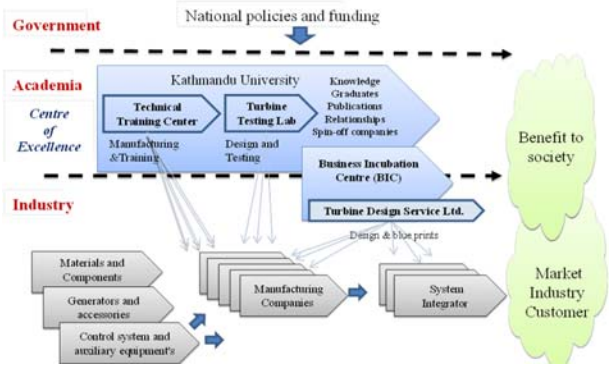

Figure 3. Model adopted by KU for transferring knowledge to society through industry [5]

With the competence and capacity built-up, TTL is implementing several international projects with industrial partnerships. The FranSed project [15] at TTL is serving as the common link to all projects at TTL. The main goal is to develop and validate the design of Francis turbines suitable for sediment-laden projects and invite manufacturers and hydropower industries to implement it on a commercial basis. With the international network developed from the research projects, a consortium of the following research centers is being formed for joint research on sediment erosion in hydraulic machinery.

I. Turbine Testing Laboratory, Kathmandu University, Nepal, (KU)

II. The Waterpower Laboratory, Norwegian University of Science and Technology, Norway, (NTNU)

III. Flow Informatics Lab, Korea Maritime & Ocean University, Korea (KMOU)

IV. Institute of New and Renewable Energy Technology Research, Mokpo National University, Korea (MNU)

V. State Key Laboratory of Water Resources and Hydropower Engineering Science, Wuhan University, China (WHU)

VI. State Key Laboratory of Hydroscience and Engineering, Tsinghua University, China (THU)

VII. Alternate Hydro Energy Centre, Indian Institute of Technology (Roorkee), India, (IITR)

At present TTL has been in collaboration with each of these institutes with one or more R&D projects. Some of the major projects within this consortium are as presented in Table 2.

TTL has introduced an international symposium Current Research in Hydropower Technologies (CRHT) since 2010 as an annual event to create a platform for aspiring researchers from the hydropower sector to share their ideas and information regarding their research activities. The papers written by researchers and students for this event are published in an international journal. Thus, KU has raised its quality of education and research.

V. CHALLENGES AND FUTURE DIRECTIONS

At present, there are nine full universities in Nepal and four medical academies offering various programs in medical, engineering and other subject areas. Government has been working to make the university education accessible in all parts of the country as the federalism has put into practice. Despite these attempts, a huge chunk of youths is migrating abroad for higher education. In the year 2018, more than 38000 students from Nepal landed in Australia alone, and most of them were for engineering education. There has been a good debate and discussions in Nepalese academia on the necessary strategies and activities to retain these students in home universities. In addition to strengthening its engineering programs and industrial research, KU has started to work on the development of joint study programs with foreign universities. Such joint programs offer the students to choose the courses offered from both universities and get the dual, joint, or individual degrees upon the completion of the program. One dual and two joint PhD

Table 2: List of international projects at TTL, KU for sediment erosion in hydraulic turbines

Project ID	Aim	Partners	Period
EnergizeNepal	Developing IEC standard test rig at TTL	KU, NTNU	2016-2021
SediPass	Erosion measurement in guide vane cascade	KU, NTNU	2015-2019
FranSed	Research on variable speed turbine	KU, IITR, NTNU	2018-2022
RenewableNepal	Research on micro-hydro Francis turbine	KU, KMOU, MNU	2018-2020
Visiting Scholar	Mechanism of sediment erosion phenomenon	KU, WHU; KU, TSU	2019-2020

level studies have been completed by KU and NTNU in the field of the hydropower sector. KU is in discussion with Western Sydney University (Australia) and Wuhan University (China) to expand such joint programs at undergraduate and post-graduate levels.

The effort made by KU-NTNU team on the development of hydraulic turbines for sediment-laden flows is not receiving as expected attention by the hydropower industry. The resistance of the business market to adapt to new technology without time-tested results has been a major challenge. Since the market of such new turbine technology is significant, there is a need for an international research center to address the research and innovation specific to the hydropower development in the Himalaya region. Issues and challenges induced by sediment-laden flows being in the main focus. This includes the design, manufacturing, and operation of the major components of hydropower systems. A new facility is being planned to be established as the 'Hydropower Research Center for Himalaya Region' (HRCHR). The main focus of this center will be to establish excellence within sediment erosion of hydro turbines. KU-NTNU team, in collaboration with the consortium partner intuitions, is taking the initiations to co-build, co-manage and co-own this facility. HRCHR aims to build an open platform for international cooperation, scientific research, and personal training. It is conceived to have the Academic, Research, and Professional service units to bring the universities, government agencies, and industries with a common vision to develop hydropower sector in the Himalaya region by addressing the technical challenges by research and innovations.

VI. CONCLUSIONS

Research, higher education, and business are the three vertexes of knowledge triangle for a society to prosper. Nepal being a developing country, with the major educational reformation introduced very lately, has not arrived at the equilibrium point of the knowledge triangle. The progress and achievements made by Kathmandu University (KU) in the last two decades have set up a milestone to progress towards a research-based university education in a developing country. The pedagogical practice, experiences, and achievements made by KU in engineering education can be a lesson learned to the other parts of the world. In particular, KU's vision to identify the research challenges specific to the country having a high and long-term socio-economic impact has strengthened its foundations and made its research visibly impactful. Cooperation with the established universities in different parts of the world to develop industry-based research cooperation and managing joint academic programs will further reinforce the academic practices in KU to establish itself as an international university in the future. KU has already begun this journey by developing the relationship with WSU in Australia to facilitate better student learning outcomes by developing and implementing hybrid learning pedagogies and using various innovative learning technologies.

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From Research to Learning and Teaching: Reflection on Experience with Postgraduate Students

Quang Vinh Nguyen
MARCS Institute for Brain, Behaviour and Development, and School of Computing, Engineering and Mathematics
Western Sydney University
Parramatta, Australia
Q.Nguyen@westernsydney.edu.au

Surendra Shrestha
School of Computing, Engineering and Mathematics
Western Sydney University
Parramatta, Australia
S.Shrestha@westernsydney.edu.au

***Abstract*— The role of a university lecturer has always been challenging as it needs to elevate the inspiration and deliver up-to-date knowledge and skills to the students. Teaching with full of supportive technologies is not necessarily an optimal approach whilst the blended learning with hybrid teaching styles can support better student needs and appropriate subject matters. This paper presents a positive experience based on the hybrid model of learning and teaching to motivate and inspire students to learn. By blending real-world research experience with extensive visual examples to teaching, we delivered high-quality teaching curriculum as well as attracted students to continue their study journey in related research projects reflecting their passions and knowledge from the former study. The leaning and teaching experience were applied to postgraduate coursework in information communications technology, data science and engineering fields.**

Keywords—hybrid model, blended learning, research to teaching.

I. INTRODUCTION

With the rapid development of science and technologies, education in the 21st century has gone beyond traditional academic walls. This has shifted our educational perspective from teacher-centred to student-centred in which information and communication technologies were used more and more to support a range of student cohorts – full time students as well as students with work and/or family commitments. The important factors that affect the teaching quality and student satisfaction include the type of course, class size, class attendance, student motivation, interaction with teachers and collaboration with classmates [1]. Technologies help to build new multimedia environments and strategies for supporting effective teaching and learning.

Blended learning is an educational approach that facilitates students to learn via electronic and online media as well as traditional face-to-face teaching. There is evidence that the right blended learning environments (i.e. mix of classroom and online) could improve student satisfactions in comparison to face-to-face teaching [1]. Similarly, flipped learning utilises online platform to support the teaching delivery through video and other media, whilst it uses traditional class time for engaging students in collaborative and hand-on activities [2]. To improve the student experience, blended approach should provide illustrated scenarios with authentic situation to orientate the students' discussion, conceptualisation and understanding in their learning. The course should have a clear guideline, formative assessment, interactive exercises and relevant materials for background information [3]. Blended learning should not just focus on technical capability of online materials and activities, but it needs to understand students' perceptions on the learning environments and support the students in their learning journey.

Unfortunately, the use of technologies in blended learning and flipped learning may create many challenges to the instructors or lecturers, such as heavy preparation workload, providing assistances to many students' request, and developing interesting and engaging online material. Thus, technologies and knowledge should be utilised for teaching curriculum and delivery in a way that they do not increase the lecturers' teaching effort and time.

One of the challenges in tertiary education is the balance and blending of research into teaching. University professors or lecturers often avoid teaching if they have interest in research, or they might abandon their students or have far less teaching commitment when doing research. This is due to the perception that teaching might dampen their research concentration and there is little benefit or correlation between research and teaching or learning [4]. In current university setting, the form of supervision and guidance to the students are less and less common. The lecturers or the professors spend their time differently in research and teaching, and there is much less connection between research knowledge and frontiers to teaching materials. In addition, large size classes also create challenges in engaging research to the students.

The gap between research and teaching is usually an issue in Science, Technology, Engineering and Mathematics (STEM) discipline. Integration of research activities to teaching and learning usually includes student engagement research activities, dissertation of research output via seminars and laboratories. By using the right approach, teachers could better engage the students in research by facilitating better understanding of knowledge and theories in STEM education. These theories have been applied to the CHANGE program

which helps to create interactive classrooms, bring cutting-edge research into lessons, improve student's research skills and support experiential learning and collaboration among the students [5].

It has been proven that research activities are important to support effective teaching and learning in both undergraduate and postgraduate education [6, 7]. Students at all levels who are involved in research are usually better engaged in their learning. It is essential to blend research activities with teaching and learning activities in a balanced and practical way. Effective learning and teaching go beyond the traditional written materials. They include more practical exercises, innovative design, interactive and engagement which usually require a strong integration of research with teaching and learning.

This paper presents our experiences that blend research to teaching and learning environment to deliver more effective and engaging experience to students in our postgraduate courses in information communications technology, data science and engineering. We also integrate different learning and teaching methods to blending with research experience to deliver an exciting environment and high-quality curriculum. The teaching experience have been very positive as reflected via student engagement, performance and feedbacks.

II. Blended Research to Teaching Framework

The role of a university lecturer has always been challenging as s/he has to deliver up-to-date knowledge and skills to the students while inspiring them at the same time. Although the traditional authority or lecture style has no longer been considered appropriate for teaching in many disciplines, other teaching styles such as a facilitator and a delegator alone may not be sufficient and effective in higher education.

A hybrid model of learning and teaching which incorporates all roles as a facilitator, a delegator, a demonstrator and a lecturer to support student needs and appropriate subject matters has been considering as one of the best modern approach to tailor the teaching styles [8, 9]. By embedding state-of-the-art related research works and tools to our teaching curriculums with the practical-based teaching and learning approach.

Motiving and inspiring students in their learning engagement are crucial to a successful teacher or lecturer. To achieve this, we have adopted not only energetic and motivated teaching way but also communicate proactively with the students in a friendly and approachable manner where we can identify my student's need to tailor our teaching approach. We made effort to put student-centred approach in the teaching with a respectful and stimulating experience to the students.

Our teaching philosophy of providing students with deep and practical knowledge with passion and friendly approach has evolved through our former experiences when we were looking for new and practical knowledge and friendly advice and support. We strongly believe that when having exciting and useful materials as well as friendly feedback and support, the students engage more to achieve better outcomes. We have delivered teaching with a friendly and dynamic approach, and with practices to re-enforce the students' knowledge and illustrated and interactive examples and demonstrations.

The flow of our learning and teaching approach is shown in Figure 1. The lectures provide theoretical knowledge, practical examples on the topics as well as illustrated state-of-the-art research works to the students. The small class-size tutorial and practical sessions reinforce the students' knowledge with practical exercises and interactive discussions on the current research and applications that were introduced in the lectures. These tutorials and practicals provide greater opportunity for the students to interact with the teacher(s) and their peers. Project based assignments provide the students further opportunity to do their research and apply the knowledge to real-world applications. These three components ensure high quality learning achieved by the students to enrich their knowledge, experience and engagement.

The rewarded achievement and practicality could potentially motivate students to do further projects or research courses so that they can go deeper in the field. Knowledge, practical works and experience in the teaching and student projects or research can also be used to reflect, update and improve teaching delivery.

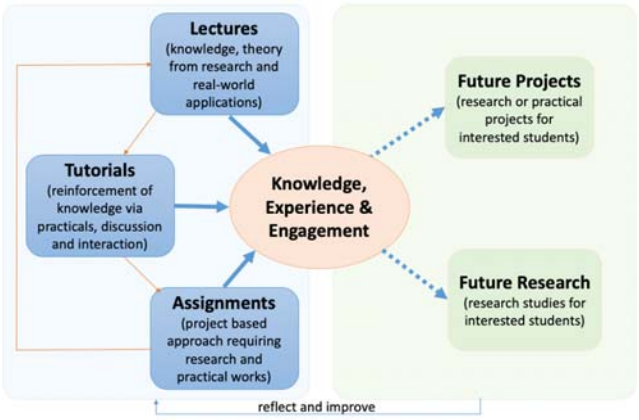

Fig. 1. The flow of learning and teaching sequence involving research to learning resources.

III. Case Study in Science and Technologies Postgraduate Courses

The study was carried out at the School of Computing, Engineering and Mathematics, Western Sydney University in Australia. The cohort consisted of students from the postgraduate programs, including Master of Information Communications Technology, Master of Data Science and other related postgraduate degrees. The majority of the cohort were international students.

A. Case Study on Teaching Mobile Computing Unit

We applied our philosophy in the development and the teaching of Mobile Computing unit which taught the students how to develop native mobile applications in both Android and iOS platforms. The class size was relatively small with approximately 20 to 30 students in each session. During the teaching period, we faced multiple challenges in the course, including i) the fast change in emerging technologies which requiring frequent update in teaching materials each year, and ii) the high diversity in quality and education backgrounds of the

post-graduate students who are mostly from overseas. Although the pre-requisite was applied to all students, some students were academically much stronger than others due to their experience in the field, especially in programming or software development.

For this unit, we applied the hybrid teaching style that focused more on the expert style where we could i) share expert knowledge, personal story and experience to the students, ii) give illustrated demonstration with a large number of up-to-date examples on the app development, and iii) include training exercises in both lectures and tutorials, as well as provide detailed and supportive feedback to the students.

Although the teaching contents of this unit were not directly applied from the authors research interest, the students were benefited from the lecturers' knowledge and experience in using technologies and app development, especially in our virtual and mixed reality research area, such as [10, 11]. By showing techniques, procedures and development processes through our real case studies, we engaged students into the practical sessions as well as provide them better guidance on the apps development. Our practical teaching also utilises our previous experience in another course where we taught the students in Tianjin university, China using project based approach [12]. In summary in the teaching in Tianjin University, we divided the master class into five groups where they carried out their research projects as the main assessment. The projects were relevant to the traditional face-to-face teaching materials.

As a result, the outcome of the student feedback on units (SFU) for Mobile Computing consistently achieved excellent scores which the mean scores of the overall satisfaction with the quality of the unit were always above 4.5 out of 5 for in years 2015 to 2018.

A further look into the results of the student feedback reveal the effectiveness of our teaching approach on most of related criteria. Table I presents the outcome of the student feedback on units which indicate not only on the excellent mean scores, but also on the broad agreement in which mostly received maximum 100% in all criteria. Table II also shows the similar outstanding outcome on the student feedback on teaching (SFT) in all criteria.

TABLE I. MEAN SCORES AND BROAD AGREEMENT PERCENTAGES OF RELEVANT CRITERIA IN STUDENT FEEDBACK ON UNITS FOR MOBILE COMPUTING UNIT. MEAN SCORE IS OUT OF 5 AND BROAD AGREEMENT (BA) IS THE PERCENTAGE OF NEUTRAL, AGREE & STRONGLY AGREE RESPONSES.

Item	Mean	%BA
Learning activities	4.50	100
Learning materials	4.50	100
Assessments	4.25	100
Technology	4.50	100
Access to timely help and advice	4.25	100
Further developed my critical and analytical skills	4.25	88
Included work related knowledge and skills	4.35	100
I was satisfied with the quality of this unit	4.50	100

TABLE II. MEAN SCORES AND BROAD AGREEMENT PERCENTAGES OF RELEVANT CRITERIA IN STUDENT FEEDBACK ON TEACHING FOR MOBILE COMPUTING UNIT. MEAN SCORE IS OUT OF 5 AND BROAD AGREEMENT (BA) IS THE PERCENTAGE OF NEUTRAL, AGREE & STRONGLY AGREE RESPONSES.

Item	Mean	%BA
Encouraging me to participate in learning activities	4.50	100
Having an effective teaching style	4.50	100
Being well prepared	4.50	100
Being approachable	4.50	100
Creating a learning environment where staff and students treated each other with fairness and respect	4.50	100
Providing a variety of perspective and evidence	4.50	100
Providing feedback that supported my learning	4.50	100
I was satisfied with the quality of this staff member's teaching	4.50	100

Our analysis on the qualitative comments also confirmed the effectiveness of the teaching methods. Some of the selected comments are "The concepts were interesting and as we use android and ios in our day-to-day life this unit was very effectively delivered and the concepts were well explained in detail and it was fun programming" (feedback from Mobile Computing 2015), "Learning technology behind creating different types of mobile apps was one of the best aspects of the unit along with the support provided by our instructor during the tenure." (feedback from Mobile Computing 2017) and "He always demonstrates the code in class and explains it, which makes it easy for us to understand the concept better. He is very encouraging. He gives us the basics and gives challenges as well for us to explore more" (Feedback from Mobile Computing 2018).

B. Case Study on Teaching Visualisation Unit

Visualisation is a post-graduate unit that covers the fundamentals and technologies of information visualisation, human-computer perception, as well as methods and tools for visual data analytics. With the fast growth of data analytics field, the class size increased significantly from less than 20 students in the earlier year to above 60 students in the later year. Similar to Mobile Computing unit, the students' backgrounds were very diverting, including Information Communications and Technology, Data Science, Business and other fields.

As this topic was directly related to one of the author's research expertise, we were able to develop state-of-the-art material, apply our deep knowledge in the visualisation field, and utilise our research works to the course development and the teaching. By reflecting on our former experience on the development and teaching methods, we improved not only the teaching design and materials, as cited "The course is beautifully designed and documented." (feedback from Visualisation 2018), but also refined our hybrid teaching method to leverage the "interaction with other students and the lecturer" in the lectures and tutorials (feedback from Visualisation 2018).

To ensure the highest quality in student's learning and teaching, in addition to providing our strong knowledge in the classes, we also used our state-of-the-art research works to illustrate the concepts, theories and tools to the students. Students often commented that "visualisation tools" and

"visualisation methods" were the best aspects in their qualitative feedback. The students indicated frequently that the "practical works" were one of the best aspects in the learning and teaching. In addition, we adopted an interactive environment in class, friendly and approachable attitude as well as extensive feedback to the students ("His enthusiasm and feedback on assignments are very valuable in understanding where to improve." (feedback from Visualisation 2017).

For example, we used i) *TabuVis* tool [13, 14] to illustrate how to visualising multi-dimensional data with scatterplots, ii) diagrammatic visualisation approach [15] to illustrate how to visualise complex multivariate logistic data, iii) Genomics visual analytics works [16, 17, 18] to demonstrate a real case study of how to analyse complex genomic and biomedical data, just named a few.

The blending of research into teaching fostered not only student development and practical skills with latest research, technologies and knowledge, but also motivated and inspired them in the learning environment, as cited "The work was very interesting and relevant to the course. Assessment layout was perfect in my opinion … Lectures were also interesting and very clear and the teacher went over everything extensively. Work load is excellent." (feedback from Visualisation 2018).

From the earlier student feedback in previous year, we revised the lecture resources in 2018 to provide more visual illustrations to break the complexity of deep technical concepts, as well as maintaining my enthusiasm, friendliness and consistency. We also provided better flexibility in the assessments to accommodate the variety in the students' strength and interests. As a result, the student feedbacks were outstanding, i.e. the Overall Experience mean scores in SFU 2018 was in the top of ranking 4.6. All other criteria in SFT 2018 survey also received 100% Broad Agreement (BA), except one criterion received little less than its perfection with 96%.

Details of the student feedback on unit (SFU) and on teaching (SFT) for Visualisation unit are shown in Table III and IV respectively. Table III presents the outcome of the student feedback on units which indicate not only on the outstanding mean scores, but also on the broad agreement in which received maximum 100% in all criteria. Table IV also shows the similar outstanding outcome on the student feedback on teaching (SFT) in all criteria.

TABLE III. MEAN SCORES AND BROAD AGREEMENT PERCENTAGES OF RELEVANT CRITERIA IN STUDENT FEEDBACK ON UNITS FOR MOBILE COMPUTING UNIT. MEAN SCORE IS OUT OF 5 AND BROAD AGREEMENT (BA) IS THE PERCENTAGE OF NEUTRAL, AGREE & STRONGLY AGREE RESPONSES.

Item	Mean	%BA
Learning activities	4.65	100
Learning materials	4.57	100
Assessments	4.57	100
Technology	4.70	100
Access to timely help and advice	4.65	100
Included work related knowledge and skills	4.61	100
I was satisfied with the quality of this unit	4.57	100

TABLE IV. MEAN SCORES AND BROAD AGREEMENT PERCENTAGES OF RELEVANT CRITERIA IN STUDENT FEEDBACK ON TEACHING FOR MOBILE COMPUTING UNIT. MEAN SCORE IS OUT OF 5 AND BROAD AGREEMENT (BA) IS THE PERCENTAGE OF NEUTRAL, AGREE & STRONGLY AGREE RESPONSES.

Item	Mean	%BA
Encouraging me to participate in learning activities	4.81	100
Having an effective teaching style	4.50	100
Being well prepared	4.58	100
Being approachable	4.88	100
Creating a learning environment where staff and students treated each other with fairness and respect	4.81	100
Providing a variety of perspective and evidence	4.81	100
Providing feedback that supported my learning	4.81	100
I was satisfied with the quality of this staff member's teaching	4.81	100

With the positive teaching experience and engagement, a number of students were motivated to take further projects in the following semesters as master projects as well as higher research studies. This reflects the learn and teaching sequence in Figure 1.

Particularly, after each teaching semester on the Visualisation unit, a number of interested students requested to do their Master projects under the supervision of the co-author. This provided opportunity to the students to extend their study in the same area as well as apply their knowledge and skills in practical and larger projects. In these research projects, the students not only studied on visualisation theory but also applied the visualisation to a variety of applications and domains, such as health data analytics, cooperate data analytics, psychology, music therapy, business data analytics.

Most of the students were very enthusiastic and engaging in their projects and thus received outstanding outcomes and grades. Particularly, the positive teaching experience made a huge impact to one outstanding Master of Data Science student who received the highest grade in his post-graduate study as well as the Dean's award. The student went on to enrol in a Ph.D. degree with scholarship from Oracle.

Our teaching philosophy and method in Visualisation went beyond its scope. Its contents had been expanding to other student cohort via guest lectures at Western Sydney University, such as for the unit Introduction to Data Science in 2016, 2017, and Information and Data Governance Law and Policy and Information and Data Governance Law and Regulation in 2018. With very positive feedback, seminars on the visualisation topic were also invited, such as at Digital Humanities group in 2017, 2018, and 'Human Rights and Privacy of My Health Data' at the School of Law in 2018.

Our blending research to teaching approach in visualisation has also recognised at events outside Western Sydney University nationally and internationally. We presented our research knowledge at the half-day course on Big Data Visual Analytics at premier event SIGGRAPH Asia 2017, BTECT, Bangkok. The course selection was very rigorous through an invitation to the experts in the chosen topics, as well as a formal review process for selection and publication by ACM (https://sa2017.siggraph.org/attendees/courses?view=session&

sid=7). We also delivered a half-day workshop on Visual Analytics and Visualisation topic at Visualisation Matters in 2017, at UNSW Art & Design (https://artdesign.unsw.edu.au/whats-on/events/visualisation-matters-2017) which was also very well perceived by the participants.

IV. Blending Research to Teaching Engineering Courses

A similar approach was adopted in two Engineering units at WSU. Advanced Water Engineering (AWE) and Water Resources Engineering (WRE) are the two units the co-author was involved in. AWE is a post-graduate unit whereas WRE is a senior undergraduate unit. The co-author was responsible for development of all teaching and learning material for both the units and was involved in 100% of teaching of both the units. SFU and SFT on the two units are listed in Tables V & VI, respectively.

The highest possible SFU & SFT score is 5.0. It is interesting to note that most of these scores were above the School and the University averages, indicating effectiveness of the learning and teaching style used by the co-author; which itself was designed and developed using the principle described on Fig. 1. It is important to note that the SFU and SFT scores were consistently lower in the undergraduate unit (WRE) when compared with that of the post-graduate unit (AWE). This is possibly due to the fact that post-graduate students have some practical experience whereas the majority of undergraduate students did not have any engineering experience.

TABLE V. Student Feedback on Units

Item	AWE	WRE
Learning activities	4.90	4.36
Learning materials	4.70	3.82
Assessments	4.70	4.00
Technology	4.70	4.36
Access to timely help and advice	4.70	4.36
Included work related knowledge and skills	4.80	4.36
Further developed my critical and analytical skills	4.67	4.45
I was satisfied with the quality of this unit	4.80	4.18

TABLE VI. Student Feedback on Teaching

Item	AWE	WRE
Encouraging me to participate in learning activities	4.78	4.44
Having an effective teaching style	4.89	4.33
Being well prepared	5.00	4.33
Being approachable	4.89	4.56
Creating a learning environment where staff and students treated each other with fairness and respect	5.00	4.44
Providing a variety of perspective and evidence	4.89	4.33
Providing feedback that supported my learning	4.67	4.67
I was satisfied with the quality of this staff member's teaching	5.00	4.67

Some of the descriptive comments include ,"… *links the teaching material to industry practices*…", "… *he tries to encourage … to explore the subject material independently to gain a deeper understanding, instead of rote learning*" and "*I witnessed and experienced his patience, understanding, availability and general interest in the unit and my learning experience. This allowed me to thrive and gain an insight into the unit and how it was being applied outside of university in my workplace. This was critical and would not have occurred without his insight and constant availability for questions and discussions regarding the unit and certain topics.*" These descriptive comments provide a much better insight into student engagement and student learning. The success of the student cohort, indicated through high pass rate with good grades are also evidences of success of the Learning and Teaching strategies developed and implemented in these units.

V. Conclusion

This paper has presented our own experiences in integrating research to learning and teaching, focusing in postgraduate Information Communications and Technology and Data Science areas and incorporating both undergraduate and postgraduate domains in Engineering. We used the hybrid model of that blended research to learning and teaching to enable high-quality teaching curriculum and exciting study environment to the students which are evidenced in the student feedback. We also create exciting and practical environments to the students where their interest can be nurtured, and their knowledge and skills can be developed. Our learning and teaching methods also encourage the students to continue their journey in various research projects or research degrees reflecting their passion to go further in the areas beyond the scope of the unit or the course.

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Study of the First Year Engineering Pathway Program at WSU: Diverse Learners

Benjamin R.W. Kelley
School of Computing, Engineering and Mathematics, Western Sydney University, Penrith, NSW 2751, Australia
B.Kelley@westernsydney.edu.au

Richard (Chunhui) Yang
School of Computing, Engineering and Mathematics, Western Sydney University, Penrith, NSW 2751, Australia
R.Yang@westernsydney.edu.au

Ragbir Bhathal
School of Computing, Engineering and Mathematics, Western Sydney University, Penrith, NSW 2751, Australia
R.Bhathal@westernsydney.edu.au

Abstract — Western Sydney University is located a significant distance outside the CBD of Sydney, with several campuses mainly located in Sydney's western suburbs. One of the unique aspects of the University is the student cohorts, who come from a diverse range of cultural and socio-economic backgrounds, and have a wide range of abilities, compared to other universities in the Sydney region.

With recent university "widening of participation" targets initiated by successive Australian governments, the intakes of students into courses like Engineering have become increasingly diverse in recent years. In the broader context of the current higher educational environment, it is therefore likely that the potential intake of students at Western Sydney University will also increase in its diversity. This led to education providers, such as Western Sydney University and its associated College, creating new pathway programs to facilitate this trend to cater for such diversity, thereby broadening student intakes within these new and also existing programs. Pathways on offer at Western Sydney University's College include an Extended Diploma, Diploma and an Associate Degree which articulate into engineering degrees, either the University's Bachelor of Engineering Science/Bachelor of Engineering (Honors) or Bachelor of Engineering Studies degree.

Students in engineering courses at Western Sydney University face many challenges and there are many aspects which can impact their success at university degree study, including issues such as student expectations, approaches to higher education, "first in family" students, experiences in diverse learning environments and other student experiences prior to course entry. There is a clear need to conduct research into how these and other factors might be addressed by the University to improve student retention and their success in a challenging subject area such as Engineering.

The aim of this research is to investigate and generate successful strategies for retention of the 1st year engineering students, using the Western Sydney University engineering pathway program as a case study, as it already has a diverse range of students. This paper specifically reviews the design and implementation of the pathways course structure with consideration to learners' diversity.

Keywords— Engineering education, first-year study, pathway program, preparatory units, learner diversity

I. Introduction

In 2009 Australia adopted a demand-driven system for university education, where student demands drove course enrolments and funding at university. This change was outlined by a *Review of Australian Higher Education Report* (Bradley et al., 2008). This change survived several successive governments and is driven by the need for a higher educated and more capable workforce.

Student retention and success are key performance indicators of modern tertiary institutions, and are key factors that can be ranked or scored on against other institutions. Australia currently lags behind other developed nations in retention, with retention rates of 59.0% for women and 41.0% for men. It is significantly behind the UK and US in this metric placing it 24th compared to 12th for the UK and 13th for the US (OECD 2019). Australia's performance has been placed under increased pressure as successive governments have sought to wider participation in tertiary education via continuing government supported places.

In addition to this, Western Sydney University (WSU) also faces challenges from its student cohorts. These challenges include students from low socioeconomic status (Low SES) backgrounds (25.4%) and students who are "first in family" to attend university (63.4%) according to the university's report – *University Plan for Success 2018-2022* (WSU 2017). This represents a particularly significant challenge for Engineering courses, which typically have significant retention issues due to the high level of Mathematics and Physics required to study in these courses and the high school sector's issues in teaching these skills in high schools to students.

There is an ongoing issue globally, within Australia and within the Greater Western Sydney region of a lack of suitable trained school teachers in the areas of Mathematics and Physics. Only 0.4% of teachers graduated with a background in Mathematics or Statistics in 2003 (Ainley, 2008) and Year 12 Advanced Mathematics enrolments fell by 34% between 1997 and 2014 (Rubinstein 2009). It has been stated that 40% of physics teachers will retire in the next 10 years (Weldon, 2015). This combined with an estimated 16.6% growth in student numbers in NSW (AMSI

2012) would imply a significantly worsening challenge to be met ultimately by the university sector.

As part of the response to this, many universities including Western Sydney University, set up pathway colleges. The College at Western Sydney University provides a range of pathway programs that feed into the corresponding degrees at the University.

II. Student Diversity Analysis

A. Geographical Location

Western Sydney University is located on several campuses and draws students across the Greater Sydney Region and beyond. There proportion of students is less in the outer areas of Sydney (Figure 1).

Western Sydney University's campuses are spread around the wider western Sydney Region with the main ones being Penrith, Richmond, Campbelltown, Bankstown and Parramatta. These typically feed from areas with lower percentages of students undertaking university study. For many students they may be alone in their peer group going to university, or in the minority. Expectations at high schools in the region also reflect this lower percentage of university study. The outer western Sydney region also reflects these long term trends with lower levels of adults holding tertiary education qualifications than in other parts of Sydney.

B. Academic Profiles

The Australian Tertiary Admission Rank (ATAR) score was introduced in 2009 and replaced the older Universities Admission Index (UAI) score, which in turn had replaced the earlier Tertiary Entrance Rank (TER). All of these ranking systems provide a score that is given to students to measure their performance at High School for the purposes of entry into university courses. The ATAR is calculated from their English performance and their three best units of study (UAC 2019). The average ATAR is designed to remain at 75.

At Western Sydney University's College, students accepted into the Diploma programs, including Diploma in Engineering and Diploma in Engineering Extended, typically have an ATAR, but it is apparently lower than that of the ATAR entry point for the Degree programs. Table I shows the Western Sydney's ATAR profile in 2018. Diploma in Engineering/Bachelor of Engineering Studies has an entry ATAR of 55.5 to accommodate Low SES students. Compared to other degrees, there is a gap of 16 at least lower than others for this combined degree.

Students in the Extended Diploma program may or may not have an ATAR at all, with entry essentially unrestricted in terms of educational background. It is also open to students entering outside of immediate high school education. Students entering the Associate Degree are extremely diverse. Many have high ATARs and are selected from competitive industry traineeships. Others may not be recent school leavers, but have extensive industry and work experience relevant to the course, including defence, medical, accounting or engineering related trades.

TABLE I. ATAR cut-offs for courses offered in 2018

Course	2018 ATAR Cut-offs
Diploma in Engineering/ Bachelor of Engineering Studies	55.50
Bachelor of Engineering Science	71.25
Bachelor of Engineering (Honors)	77.50
Bachelor of Engineering Advanced (Honors)	95.00

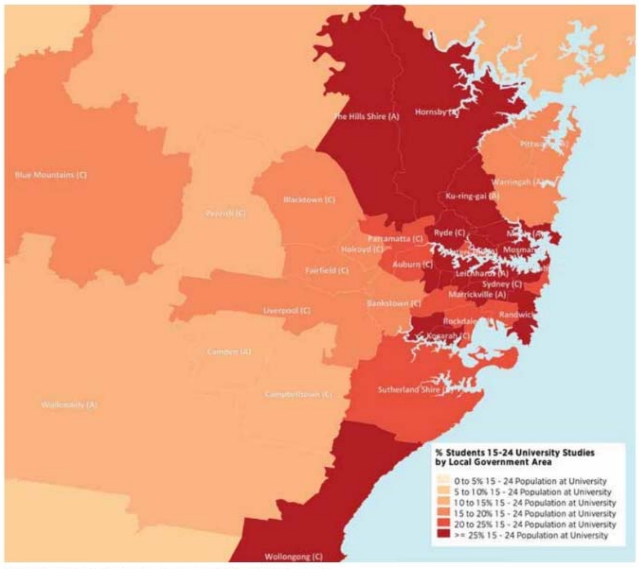

FIGURE I - University participations (15-24 year olds) by Local Government Areas (WSU 2019).

TABLE II. Student prior experience profiles by arranged by course (adapted from Data from the Course Admission Transparency report, WSU 2019)

Degree Course	Higher education study[1]	VET study[1]	Work + Life[2]	ATAR[3]	Other[4]
Diploma in Engineering	N/P	8.8%	10.5%	59.6%	19.3%
Diploma in Engineering Extended	0%	0%	42.3%	0% (no cut-off?)	54.9%
Bachelor of Engineering Science	N/P	N/P	N/P	31.4%	25.7%
Bachelor of Engineering (Honours)	16.5%	4.1%	7.1%	2.2%	43.1%
Bachelor of Engineering Advanced (Honours)	62.5%	0%	0%	0%	37.5%

N/P = Not reported
[1] = Previous studies prior to starting at WSU
[2] = Previous work or life experience reported by students
[3] = Students entering with an ATAR score lower than the course ATAR cutoff ?
[4] = This category includes students admitted solely on the basis of ATAR, Admitted where both ATAR and other criteria and admitted on the basis of other criteria only and ATAR was not a factor

Table II provides more details on the students' entry details, which actually indicate the students taking Engineering Diploma Programs have more work-based experience and are mature students.

III. Course Structure and Overview

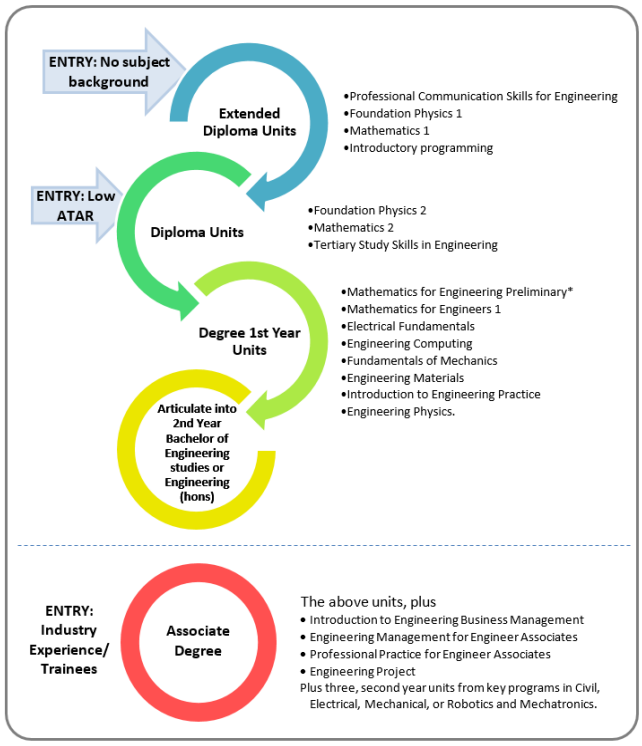

FIGURE II. Course Structure and overview

The above shows the general pathways and entry points into each of the Engineering courses available at Western Sydney University's College are shown in (FIG II). It should be noted that there is still a diverse mix of students at all levels. For example, students with higher ATARs might still choose to do the Extended Diploma course, particularly if they are worried about a weakness in their academic background, such as not studying or not performing well in Mathematics or Physics at high School.

An analysis of student profiles when entering both the University and College courses are shown in Table II. WSU's College runs on a trimester yearly timetable. Therefore, in one year, students can complete the preparatory Extended Diploma units (if needed), the advanced preparatory Diploma units, and units from the 1st year university degree which they wish to articulate into. Over the course of a year they can essentially "catch up" and if successful they can transfer to the 2nd year at university.

Students that enrol in the Extended Diploma and complete Foundation Physics 1 typically have an ATAR less than 55 and typically have not attempted any Physics or Engineering courses at High School. Students who have achieved an ATAR of 55, but fell below the entry ATAR cut-off for direct University entry (see Table I), typically enrol at the College in the Diploma of Engineering course. These students are very diverse, and may have attempted Physics, but either performed poorly or discontinued studies in Year 11. In addition, there may be some continuing students, who have completed Foundation Physics 1.

A. Preparatory Units

At High Schools, students are increasingly directed away from STEM units that would prepare them for university study, to units that have strong enrolment, are easier to staff and are seen as "safer" ATAR units for the students and the schools. Students hoping to pursue an Engineering degree may therefore need to work on their knowledge of key areas in order to be at a level that will lead to a more successful university experience.

The Extended Diploma units (i.e. the preparatory units) offered at WSU's College are designed to bridge a student's skills and knowledge between High Schools and University. The key areas covered are Mathematics, Physics and Programming. In addition to this, students also need to undertake a unit to build communication skills, which builds student's academic study skills and English abilities. Once the Extended Diploma units are completed, students continue to build their knowledge by completing advanced preparatory Diploma units in the same areas.

As Van den Broeck et al. (2018) previously found that students undertaking bridging units had troubles with the pace, depth of learning and the more theoretical approach needed during university study, the more preparation should be conducted beforehand. It was found, however, that once students passed their bridging course and transferred to the corresponding university course, they experienced lower anxiety level compared to traditional first year students, most likely because they now already had some university experience and some success.

While students have knowledge and skill gaps in Mathematics and Physics, these students also face issues around being; "first in family" to attend university, from a low SES background, having a higher proportion of students working part time jobs and other factors that limit student success and retention.

IV. Academic Performance and Progression

The Australian Government published data for 2015-2008 that indicates that across the nation, in university degrees related to Engineering and Technologies, courses have an approximate 63% completion rate as shown in Table

III, which is not high enough to Engineering Educator's point of view.

TABLE III. Engineering and Related Technologies Degree completion rates (adapted from Department of Education report, 2005-2013)

Year	Completed (any year)	Still enrolled at end of the 6 year cohort period	Re-enrolled but dropped out	Never came back after first year
2005	63%	18.2%	12.4%	6.3%
2006	62.8%	18.4%	13.1%	5.6%
2007	62.9%	18.8%	13.1%	5.3%
2008	62.0%	18.6%	14.5%	4.9%

A. Student Performance Data

Students on completion of a unit are awarded a final mark and grade for the unit. If they pass the preparatory unit, they are then allowed to proceed to the following unit at higher level. On occasion, some students have pending results and are allowed to continue their studies even if later they are awarded a mark that is not a passing grade. For all units in this paper the passing grade is 50 out of a total of 100. Students who did not successfully complete the unit were left out of the analysis so a clearer review could be made regarding student progression.

Figures III and IV show performance data of College students completing a preparatory unit (Foundation Physics 1) against their performance in an advanced preparatory unit (Foundation Physics 2) versus their marks in the following degree level unit (Engineering Physics). A tale can be seen at the bottom of each graph, where students pass the previous unit, but then score lowly on the following unit. Both graphs show the wide spread of student performance at the College in the engineering units.

Despite the streaming that occurs through ATAR's and other entry restrictions, high performing students are still intermixed with more struggling students at all levels. High performing students may have had other issues relating to ATAR or performance at High School, that when removed outside those environments are no longer an issue.

There is a strong correlation between student performance in the first preparatory unit and the success they experience in later units.

V. CONCLUSIONS AND RECOMMENDATIONS

Student performance in one unit generally correlates with the performance in the following unit, however, there seems to be some complications in the relationship with the preparatory foundation units and the degree level unit – Engineering Physics. Possibly indicating more work could be conducted on fundamental concepts and general preparation.

It seems likely that student diversity is to further increase, given the changing nature of Western Sydney, its leading status as a location for migrants to Australia and its higher ESL proportion, its economic diversity, its historic

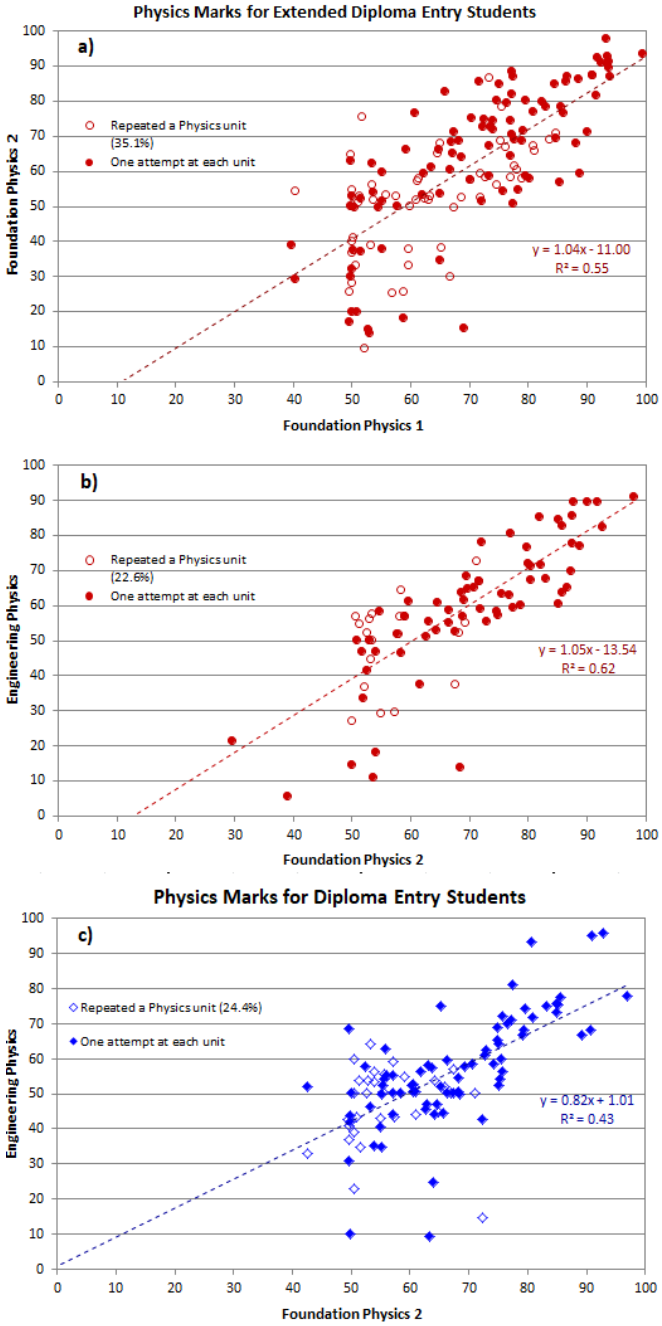

FIG. III. College student's class marks in 2018 Foundation preparatory unit Foundation Physics 1, compared to the advanced preparatory unit Foundation Physics 2

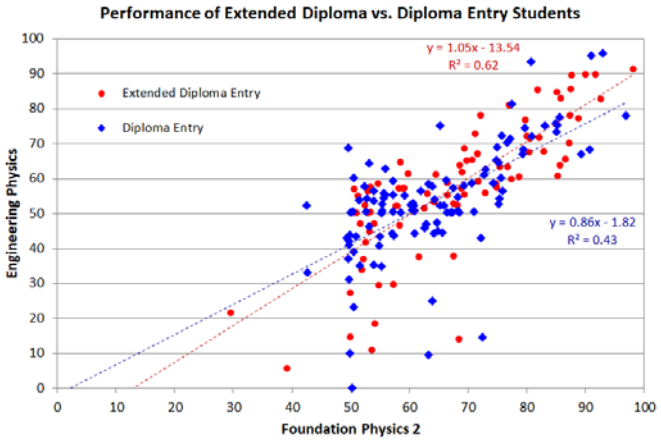

FIG. IV. a) College student's class marks in 2018 for the advanced preparatory unit (Foundation Physics 2) versus their corresponding marks for the following 1st year university level unit (Engineering Physics). b) Class marks have colour coded to show which students entered at the Extended Diploma level (red circle), and those that entered at the Diploma level (blue diamond).

Future curriculum development could specifically be designed around the unique influencing factors and needs of students intending to study at Western Sydney University and its wholly owned College entity. Peer to Peer learning is likely to be a key component in addressing many of these challenges in curriculum and in supporting studies. Embracing the diversity could result in Western Sydney Students being better prepared for workplaces and employment with greater international cooperation, challenging projects involving team members from diverse backgrounds and specializations and work places.

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Incorporating sustainability aspects in teaching of fluid mechanics: a case study in Western Sydney University, Australia

Ataur Rahman
School of Engineering
Western Sydney University
Sydney, Australia
a.rahman@westernsydney.edu.au

Rafiqul Islam
School of Engineering
Western Sydney University
Sydney, Australia
r.islam@westernsydney.edu.au

Jenis F Islam
School of Engineering
Western Sydney University
Sydney Australia
jenisislam04@gmail.com

***Abstract*—Fluid mechanics is taught in engineering schools as part of civil, environmental, chemical and mechanical engineering degrees. This paper explores how sustainability can be better incorporated into the fluid mechanics syllabus. An informal student survey demonstrates the strong desire of the currently enrolled students in fluid mechanics subject in Western Sydney University (WSU) to learn more on sustainability issues. An updated syllabus of fluid mechanics is proposed with relevant sustainability topics to enhance the students' understanding and competency in applying sustainability principles in fluid engineering applications. A necessary consultation process within WSU and Engineers Australia should be undertaken to materialise the new sustainability rich fluid mechanics syllabus.**

Keywords—fluid mechanics, sustainability, engineering, curriculum, syllabus.

I. INTRODUCTION

Most of the life forms in this planet are immersed in a fluid (either the atmosphere or the water), hence it is argued that life is bathed in fluids [1]. The domain of fluid mechanics is very wide such as blood flow in animal's blood circulation systems, dropping of rains from sky to ground, flow of water over land surface and water bodies, water movement in plant bodies and flow of fluid in pipes. Fluid mechanics deals with pressure, velocity and energy in the body of water in both static and dynamic states. Fluid mechanics is taught in civil, mechanical, environmental, aeronautical and chemical engineering courses as these disciplines have to solve numerous problems involving fluids such as water supply, irrigation, transport of gases, fluid flow hydraulic and building service systems, and drag and lift of airplanes.

Fluid mechanics is generally taught in the second year of undergraduate engineering courses [2, 3]. Teaching and learning of fluid mechanics is regarded a challenging task due to its complexity and mathematical nature that is quite different to learning of mechanics of solid materials [4]. Fluid mechanics include large numbers of variables and equations to explain fluid flow in space and time, which is found to be difficult to grasp by most of the students. There have been number of studies focusing on the learning and teaching aspects of fluid mechanics [5, 6, 7].

Sustainability education has become a priority to many disciplines as a response to meet the UN's Sustainable Development Goals (SDG). Teaching and learning of fluid mechanics is relevant to multiple SDGs such as SDG 6 Clean water and sanitation (e.g. efficient transportation of water along pipes and drains utilizing gravity as much as possible rather than mechanical pumps); SDG 7 Affordable and clean energy (efficient flow of gases through supply network and solar pumps); SDG 9 Industry, innovation and infrastructure (computational fluid dynamics, off-shore gas industries, water pumps and valves); and SDG 11 Sustainable Cities ad Communities (fluid systems in the built environment). Trad et al. [8] noted that Education for Sustainable Development (ESD), a key enabler for all the 17 SDGs, has not been well adopted in undergraduate engineering curricula. Based on a study involving ten Australian academics, they noted "these academics perceive sustainability as a technical concept, presumably taught by someone else in the curriculum and as a result, sustainability is mostly invisible within undergraduate engineering curricula".

Kumar et al. [9] evaluated the undergraduate mechanical engineering curriculum at Michigan Tech (USA) in relation to sustainability and noted the possible barriers to incorporating sustainability in the curriculum. They noted that mechanical engineers must understand the full impacts of their decisions to contribute towards societal efforts to minimize negative anthropogenic impacts on the economy, society, and environment. Mechanical engineers have a direct input to sustainable development projects such as wind and solar energy, hydroelectricity and smart materials. They concluded "infusing sustainability into engineering curricula, including course development and engaged faculty, will provide students

with the tools to confront the challenging issues in achieving a sustainable world".

Recently Islam [11] highlighted the need for sustainability education itself is an achievement of SDG 4. Islam [11] indicated that in every living activities of a world citizen should consider sustainability noting "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 actions) 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". The study of Fluid mechanics has very strong position in the way engineers designs lifestyle components of the current society thus introduction of sustainability in this subject is highly appreciable.

Most of the traditional fluid mechanics text books hardly contain practical problems on sustainability issues relevant to fluids, and hence students are not being well prepared to make innovations in this field to enhance sustainability. As an example, Sydney Water Corporation is one of the highest power consumers in New South Wales State, Australia where pumping of water and sewage is the main component in the power bill. Design of a more efficient water and sewage transportation system is possible utilizing the sustainability principles, such as use of gravity and solar pump as much as possible (e.g. pumping of sewage during day time using solar power in mini plants) instead of mechanical pumps.

This paper proposes amendment of fluid mechanics syllabus in Western Sydney University (WSU) to incorporate more sustainability aspects to meet the growing need of the industry and society. An informal student survey is carried out to evaluate the desire of the students in WSU (currently enrolled in fluid mechanics) to learn sustainability aspects of fluid engineering. .

II. Overview of Fluid Mechanics in Relation to Sustainability

A quick search on fluid mechanics courses in Australian universities (Table I) reveals that the current syllabus does not focus on sustainability, rather on fundamentals and mathematical modelling. Although only four universities are shown in Table I, it is likely that other universities have similar course outline where sustainability is not highlighted.

Sustainability energy fundamentals, a postgraduate subject in RMIT university, includes fluid mechanics topics (subject outline "This course will cover the 'physics of energy', including thermodynamics, heat transfer, fluid mechanics, chemistry of energy, and electrical energy, up to a master's level. The emphasis will be on theory and practical methods that are particularly relevant to sustainable energy technologies and systems."

TABLE I. Subject Contents of Fluid Mechanics in an Universities

Subject	***Institution***	***Subject outline highlighted (partially)***	***Sustainability aspects***
Fluid mechanics	Western Sydney University	This unit provides a basic understanding of fluid mechanics principles. While the main focus will remain on incompressible fluids, effects of compressible fluids will also be discussed. The theories learned in classes will be reinforced in laboratory sessions.	Word sustainability does not appear in the subject title or outline.
Fluid mechanics	University of New South Wales	Fluids in static equilibrium. Buoyancy. Pressures in accelerating fluid systems. Steady flow energy equations. Flow measurement. Momentum analysis. Dimensional analysis and similarity. Pipe flow. Pump and pipeline system characteristics.	
Mechanics of fluids	Monash University	This unit develops the students' physical understanding of fluid statics and fluid flow and the interaction of fluid forces with solids.	
Fluid mechanics	Queensland University of Technology	This unit introduces the student to the concepts of fluid mechanics in the context of real engineering systems.	

Fluid dynamics of sustainability and the environment subject, jointly offered by Ecole Polytechnique (Paris) and The University of Cambridge (UK), for PhD students, postdocs and engineers has incorporated sustainability in a greater depth. The subject outline states "The fluid-dynamical aspects of energy transition and climate change are covered in breadth and in depth. The principal aims of the school are, on the one hand, to give students an advanced understanding of geophysical and environmental fluid dynamics, and, on the other hand, to foster community networking among current and future researchers in these critical fields of science and technology". Environmental fluid dynamics subject in the University of Notre Dame (USA) has incorporated few sustainability aspects with the keywords "Nature", "Sustainable Plans" and "Climate Change".

III. Methodology and Results

Before The students enrolled in fluid mechanics subject in autumn 2019 semester in WSU were asked ten questions (Table II) to assess the relevance of sustainability in learning this subject. The choice of participation was open to all 240

students from two campuses of the WSU. To eliminate any biasness, all participants were given the same briefing by the same lecturer and the handing out the questionnaire was anonymous. Sixty eight students responded in this informal survey. About 93% of the responders expressed their concerns with the climate change due to anthropogenic interventions/roles. Only 29% of the respondents are aware of the UN's SDGs, which is quite disappointing as these students are in their 2nd year of the university and have completed high schools and one year of university education. About 88% of the respondents believe that sustainability concepts must be studied in all the relevant subjects in Australian universities. About 76% of the respondents state that a greater content on sustainable methods should be introduced in fluid mechanics curriculum as compared with the current content, which is dominated by mathematical perspectives. The results from this informal survey have motivated the authors to take necessary steps in updating the syllabus of fluid mechanics subject.

The current syllabus of fluid mechanics subject in WSU is shown in Table III (column 2). The proposed syllabus to enhance sustainability education in relation to fluid mechancis is provided in Table III (column 4). This however, needs more debate/discussion among the relevant staff and students of the university and Engineers Australia (the course accreditations body in Australia). A blended learning approach (e.g. Video Clips and on-line quizzes) can be applied to incorporate sustainability aspects in the new fluid mechanics syllabus.

TABLE II. QUESTION TO STUDENTS ON SUSTAINABILITY

ID	*Description*	*% responded "yes"*
1	Are you concerned with climate change due to human practice that is impacting the planet and the living climate negatively?	93
2	Do you believe that the human lifestyle is affecting the planet's resources and the climate is unsustainable?	88
3	Are you aware that there are 17 Sustainable Development Goals laid out in the United Nations climate change mitigation program?	29
4	Are you aware that Australia is not meeting its target sustainable development goals as on today?	42
5	Do you believe that climate impact is a global phenomenon and not meeting these goals will have a boomerang effect to the life of future Australians?	88
6	Do you care that all global citizen must have fair share of resources needed to sustain their lives (food, water, energy, shelter, cloths etc.)	85
7	In respect to sustainability, will you actively promote global participation from your own life to all global citizens?	76
8	Do you propose that sustainability concepts must be studied in all relevant subjects in all universities in Australia so that youths can get ready to make the planet sustainable?	88
9	Did you find that studying the subject 300762 Fluid Mechanics at the WUS brought you understanding of resources, energy and emissions impact of fluid systems and associated infrastructure design or operation?	72
10	Do you propose that more content on the sustainable development methods to be introduced in this subject than the current content?	76

TABLE III. CURRENT SYLLABUS OF FLUID MECHANICS SUBJECTS AT WSU AND THE PROPOSED SUSTAINABILITY TOPICS

Lecture	*Current topic*	*Proposed topic*	*Proposed new sustainability topics*
1	Fluid properties	Fluid properties Sustainable Development Goals (SDGs): relation to fluid engineering	Group discussion/in-class debate on SDGs. Relate fluid properties to climate factors such as energy consumption and environmental impacts.
2	Fluid statics	Fluid statics	
3	Bernoulli equation	Bernoulli equation	Climate change issues that relate to fluid engineering.
4	Types of flow and continuity equation	Types of flow and continuity equation	Case study on environmental impacts of erosion and how water flow can be regulated to minimize erosion in natural channels. Case study on atmospheric circulation and ocean current changes due to global warming.
5	Energy equations	Energy equations Introduction to mechanical and solar pumps using real examples	Case studies demonstrating energy savings in fluid flow such as use of pumps in rainwater and sewage systems.
6	Momentum	Momentum	Case study on dam break analysis showing sediment movement and its environmental impacts
7	Dimensional analysis and similitude	Dimensional analysis and similitude	
	Semester break	Semester break	Semester break
8	Flow in conduits	Flow in conduits	Case study on water transport via pipes and open channels in irrigation projects. Solving example problems demonstrating how conduit design affect energy resource consumption, greenhouse gas emission and operating costs. Students should be able to make a sustainable design choice.
9	Open channel flow	Open channel flow and flow measurements	Case study on a local irrigation project in Australia. Sustainable irrigation canals and examples of failed irrigation projects and associated societal issues.
10	Flow measurement	Drag and lift	Case study on determining impact of drag and lift on design of vehicle and airplanes.

Lecture	*Current topic*	*Proposed topic*	*Proposed new sustainability topics*
11	Drag and lift	Sustainability for mechanical and solar pumps, wind turbines and hydroelectricity generation.	Case study on mini hydro-electricity generation using energy of water supply systems and small dams.
12	Reflection and revision	Reflection and revision	Review of selected journal articles on sustainability in fluid engineering.

IV. Conclusion

The teaching and learning of fluid mechanics in Western Sydney University is presented. It has been found that the current syllabus of fluid mechanics does not provide adequate focus on sustainability. An informal student survey in WSU demonstrates the desire of the students to learn more sustainability topics in fluid mechanics. About 76% of the respondents state that a greater content on sustainable development methods should be introduced in fluid mechanics syllabus. A revised syllabus of fluid mechanics is formulated for WSU engineering degrees where possible sustainability topics are proposed. It is recommended that other universities and educational institutions adopt similar adjustment to engineering subjects, including fluid mechanics in the similar manner to fast track of the UN SDG achievements.

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Multidisciplinary Student-Led Project-Based Learning in Engineering

Ali Hellany
School of Computing, Engineering, and Mathematics
Western Sydney Univesity
Sydney Austalia
a.hellany@westernsydney.edu.au

Mahmood Nagrial
School of Computing, Engineering, and Mathematics
Western Sydney Univesity
Sydney Austalia
m.nagrial@westernsydney.edu.au

Jamal Rizk
School of Computing, Engineering, and Mathematics
Western Sydney Univesity
Sydney Austalia
j.rizk@westernsydney.edu.au

***Abstract*—. Project-Based Learning (PBL) is identified as a comprehensive student-centered approach in engineering education. This paper offers an advanced form of PBL, the Multidisciplinary Project-Based Student-Led Learning (MPBSL). It describes the potential Learning technical, industrial, educational, social, and cultural outcomes and competencies that are achieved through MPBSL. Besides, this paper provides case studies of three projects that implemented MPBSL in the Engineering Program.**

Keywords— Learning Styles, Project-Based Learning (PBL), Multidisciplinary Project-Based Student-Led Learning (MPBSL)

I. INTRODUCTION

Educators in Engineering apply various learning styles to offer students a learning experience that will prepare them for the global job market after graduation by developing crucial skills needed in the 21st century. These skills revolve around critical thinking, problem-solving, and analytical abilities so that they can perform at an advanced level of thinking. These learning styles oscillates between teacher-centered and student-centered approaches. Many prominent educators suggested PBL for teaching, one of the earliest was W. Kilpatrick in his article "The Project Method," published in 1918 [1]. The traditional lecture-based pedagogy models that treat students as passive recipients with linear and fragmented teaching presentations have been criticized for depriving students of the opportunities for learning the holistic nature of the discipline [2]. Recently, PBL gained more attention based on the suggestions of many educators, to consider it as a useful pedagogical approach in teaching [3-4]. Recently, educational reforms aim to shift Learning practices away from teacher-centered to more learner-centered [5-7].

PBL views learning as a natural process of student interactions and reflections of ideas and experiences [8]. PBL provokes serious thinking as students acquire new knowledge and learn by pursuing solutions, e.g., raising questions, debating ideas, designing plans, and communicating with others. These activities are an essential component of PBL that drives student activities and the "final product". David Kolb states that experiential learning is a multidimensional process. It begins from concrete experience to reflective observation, to abstract conceptualization to active experimentation [9]. The teacher acts as facilitator, working with students to frame essential questions, structuring meaningful tasks, coaching and carefully assessing the experience" [10].

Several studies have found that PBL enhances content Knowledge due to the increased student's motivations and positive attitude towards learning [11-12]. An earlier comparative study found out that the traditional teacher-centered instruction developed develop procedural knowledge based on information recall while PBL learning activities developed conceptual understandings that required deeper thinking [13]. However, other studies point out that PBL may lead to the so-called "Social loafing" where some members may have lower performance that goes unnoticeable or the whole production of a team can be lowered to keep the collegial adherence [14].

The necessary skills of any professional in the 21st century requires working collaboratively, decision-making ability, and thinking innovatively, PBL is proved as an effective method in achieving these skills [15]. The PBL helps in developing student's emotional characters and social elements and reducing student's anxiety [16]. It also allows students to perform at a higher level of thinking (HOT) with two skills curricula: the process of constructing knowledge and developing learner curiosity [17].

II. MULTIDISCIPLINARY AND STUDENT-LED APPROACH

Typical projects are conducted collaboratively and focus on topics that drive students to encounter the central concepts and principles of one or more disciplines. Projects are long term, realistic, with an apparent outcome. The line between engineering and other professional disciplines but is shrinking At Western Sydney University (WSU) various disciplines such as Engineering (Civil, Mechanical, Electrical), Construction Management, Industrial Design, Media, Business, and Medicine programs are attempting to bring the disciplines together in the form of a multidisciplinary project/s. The challenge of interdisciplinary projects is to overcome the lack of understanding of what other profession and their methodology. These barriers can be overcome by allowing students who were formerly segregated by classes to work together as a cohesive unit to solve problems.

The importance of a multidisciplinary approach to supplement traditional mono-discipline learning is well recognized in the field of Engineering and other fields [18]. The opportunity can enhance acquiring knowledge [19]. Roger and Badger [12] have compared an engineering capstone design course with multidisciplinary project teams against monodisciplinary project teams. The results showed that the performance in innovation, utility, analysis, proof of concept, and communication skills was superior for the multidisciplinary teams [20]. The students in engineering programs need to be exposed to multidisciplinary environment at an early stage in their undergraduate career. The multidisciplinary approach can enhance their contribution as an engineer and team leader.

Further, it is necessary to guard against a "discipline superiority" or a "discipline exclusivity" mindset. The students should develop appreciation, respect, and willingness to learn from engineering disciplines different from their chosen specialization as an undergraduate [21].

The student-led concept was part of the reflective process during the early stage of project development. The basic idea is to empower students and to work in collaboration with the faculty in deciding aims and concepts. The students must have real input on how to manage and shape the expected outcomes of projects. The management will ensure the student input while the faculty members supervising the project are aware of the overall progress

III. Team Structure

The team structure is to be flexible to suit each project. However, the general trend is for the academic supervisor to oversee the whole project and be able to assist when required. The primary driver for the project needs to be the team manager supported by group leads and a project administration member. Few academic mentors are to be available to advise on technical or design aspects, as shown in Figure 1for a successful sustainable house project at WSU.

IV. Learning Outcomes and Competencies

Learning outcomes and competencies achieved through MPBSL are divided into Technical, Industrial, Educational, Social, and Cultural.

MPBSL can offer a platform for students to perform hands-on experience innovatively and creatively. The first step is to appoint a team manager and group. The academic supervisor can initiate this by inviting EOI that will outline the work. The team will be responsible for developing the concept/story/idea and literature review for initial learning, validation of ideas, and comparison. This will require the team to engage in a self-learning process with the mentoring guidance of the academic mentors. The self-learning experience is essential as it establishes a trend of the professional attitude of graduates. Another critical aspect of the work is for the team manager and academic supervisor to focus teamwork mentality amongst team members. This collaborative attitude is one of the essential ingredients of success and smooth progress of the project.

The team manager and the group leads will develop an understanding of the need to implement a proper project management approach to proceed successfully, e.g., Gantt chart management tools such as ASANA, Slack, and other software suitable for the undertaken project. The team leads need to agree on information storage (data, design, media, documents) and the proper handling of access usage and handling. The Team manager and admin assistant will establish a communication procedure (email, messenger, phones). This aspect of project management is to be established early in the life of the project.

Work Health and Safety (WHS) is an essential aspect of the project. The team members are required to actively participate in the training of a risk assessment for various activities. If the project involves the use of tools and machinery or building, then members have to complete general induction training and specific training on machines that they operate during the period of their engagement in the project. Technical Support Officer (TSO) and the academic supervisor will ensure compliance with all WHS rules and directives. In some cases, first aid training is to be conducted for some of the team members.

If the project requires the involvement of an industrial partner/s, then this will be handled by the team manager and group leads. It can be an excellent opportunity for team members to get familiar with the industrial code of practice and the latest technologies, approaches, and practices in the industry.

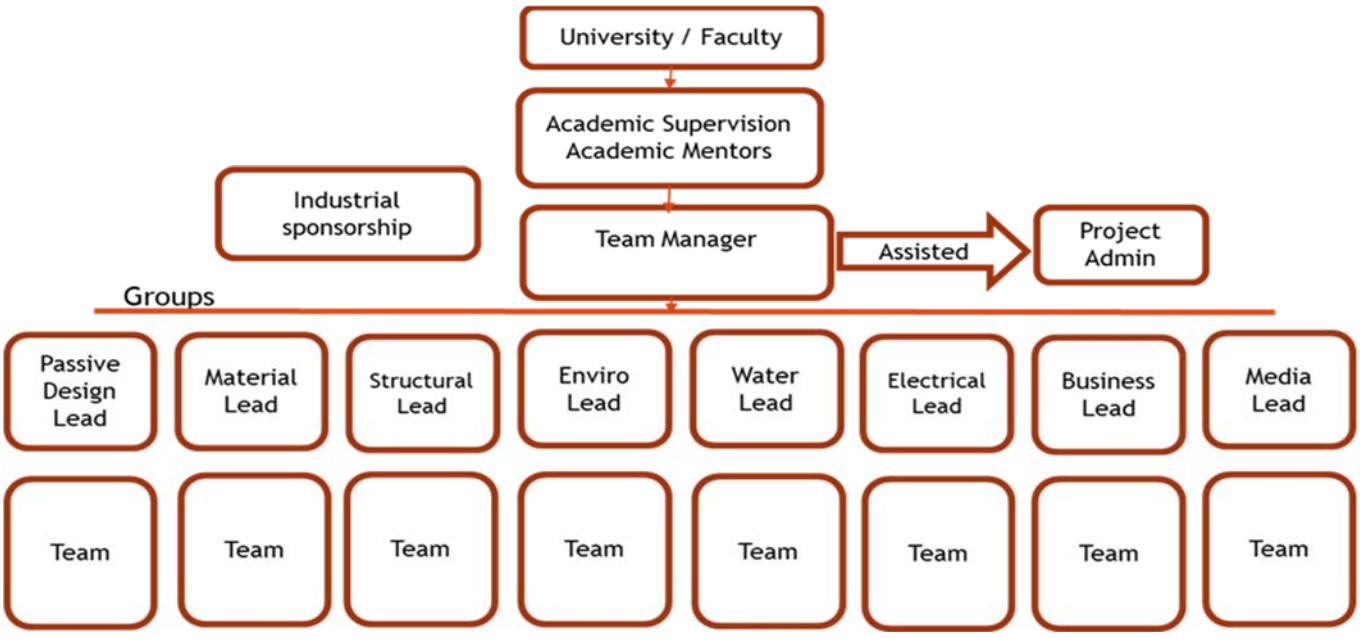

Fig. 1. The Sustainable House Project structure

The industry partners are always keen to support student projects as a recruitment exercise for potential future professionals. This interaction between the project team members and the industry offers a real-life industrial experience that complements their self-learning experience.

One of the most challenging aspects of MPBSL is its multidisciplinary nature. The students will deepen their knowledge in their field of expertise with literature review and design calculations further analysis. Many students, this will be their first encounter with real-life work, and they eventually learn to balance the demands of their specific task and the work of other aspects of the project.

The nature of these projects is continuous and of cyclic nature. The team management will change at the end of the cycle with new recruits. This will offer an opportunity for the team leads (manager and group leads) to practice an active leadership role and for every team member to practice some mentoring role. The leadership quality is one of the professional competence highly sought after in the industry for new graduates.

Each project will have a business group that will look after the financial viability of the project, attracting sponsorship from the relevant industry and entrepreneurship possibility of any element of innovation that may result from the project. Most of the leads will participate in the development of the project business case, procurement, and purchasing process, including competitive quotations and economical solutions.

The project is open to everyone, and the team members have diverse cultural, gender, ethnic, and socio-economic background. The team works closely and long hours and also engage in social activities. In some cases, international collaboration or competition is an integral part of the project. It can present an opportunity for global interaction, cooperation, partnership, and understanding the multicultural experience of the team members(for example, World Solar Challenge, Solar Decathlon).

It is critical to select/offer a project to raise the student's social awareness and spread the view that engineering solutions should primarily serve people and society. Engineering should provide sustainable, affordable solutions and offers a safer, accessible, and convenient lifestyle. The UN 17 Sustainable Development Goals (SDGs) can serve as a guideline for the projects. The following is a list of the relevant goals:

- Goal 1, No Poverty
- Goal 2, Zero Hunger
- Goal 3, Good Health and Well-being
- Goal 4, Quality Education
- Goal 5, Gender Equality
- Goal 6, Clean Water and Sanitation
- Goal 7, Affordable and Clean Energy
- Goal 9, Industry, Innovation, and Infrastructure,
- Goal 11, Sustainable Cities and Communities
- Goal 12, Responsible Consumption and Production
- Goal 13, Climate Action
- Goal 14, Life Below Water
- Goal 15, Life on Land.

V. Case Studies

The School of Computing Engineering and Mathematics at WSU have developed multiple projects with MPBSL approach:

- **Western Sydney University Solar Car**. This project started in 2011 and was offered for undergraduate, postgraduate students, Alumni, and industry personnel. More than 1000 members participated in this project during the past nine years. This project involved building four solar cars and participated in 5 international solar car races.
- **Hybrid renewable energy station (Werrington South)**. This project commenced in 2016 and is offered for undergraduate, postgraduate students, alumni, and industry personnel. More than 100 members have participated in this project during the past three years. This project has resulted in the construction of a 10 KW solar/wind energy station, which is supplying the university grid and is available for students for training and research.
- **Sustainable House Project**. This project started in 2014 and was also offered for undergraduate, postgraduate students, Alumni, and industry personnel. More than 400 members have participated in this project during the past five years. This project had three cycles of leadership change and resulted in the design of two houses. The team is collaborating with an international team and planning to participate in the Solar Decathlon in 2020.

VI. Challenges

The major challenge is the educator's lack of training and experience in implementing the MPBSL approach. This type of learning style requires more effort and dedication from educators. It requires extra time for the preparation of new materials and to manage and mentor the students. Based on the experience from implementing the above three projects, the best way is to offer these projects as final year capstone projects to guarantee the continuity of the project with students from all levels, undergraduate and postgraduate, as volunteers. Students are supported by one full-time technical support officer who handles the purchases and facilitates their work in the faculty workshop. The volunteering nature work can impact the progress of work as it can slow down during exam periods and academic breaks.

VII. Conclusions

Multidisciplinary Project-Based Student-Led Learning (MPBSL) has proved to be an inspirational experience for students. It presented a motivation for both students and lecturers who participated in it. MPBSL can complement the traditional learning styles in Engineering and assist in preparation for the global job market and increase the employability of engineering graduates. It can also result in economical solutions to many technical problems.

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First year in the university: A case study in Sydney, Australia

Sumya Rahman
EnviroWater Sydney, Plumpton,
New South Wales, Australia
sumya.rahman95@gmail.com

Sahir Mahmud
Western Sydney University,
Sydney, Australia
sahir.mahmud@hotmail.com

Tarek Rahman
EnviroWater Sydney, Plumpton,
New South Wales, Australia
tarek435@gmail.com

Kamal Mahmud
EnviroWater Sydney, Plumpton,
New South Wales, Australia,
kumahmud@hotmail.com

Jenis Islam
Western Sydney University,
Sydney, Australia
jenisislam04@gmail.com

Ataur Rahman
Western Sydney University,
Sydney, Australia
a.rahman@westernsydney.edu.au

***Abstract*—This paper presents a study on first year university students who often lack in motivation and discontinue studies or show poor performance. It presents how students in early years of university studies face difficulties in selection of courses, friends, and interaction with lecturers and other university related aspects. It has been found that lecturers and tutors have a larger role to play to connect with students and also senior high school students may need training/seminars to understand university life to reduce the rate of drop-out and unexpected examination results. This preliminary study should be extended to a larger sample size to confirm its findings.**

Keywords—First year, motivation, drop-out, learning

I. Introduction

In Australian universities, many students leave university before graduation. This study is devoted to investigating the motivation and preference of first and second year university students to find a relation with the issue of increasing retention rates in Australian universities. The drop out rate from Australian universities is quite high and it is a major issue. The significant scale of this problem is stated by Norton and Cherastidtham [1]; they stated that out of all the students who will begin university in Australia this year, more than 50 000 of them drop out. There could be several reasons and factors for why a student may decide to drop out of university. One factor could be in relation to the study load a student may take on during the semester. Koziol [2] stated a student who chooses to undertake a part time study load in university; he or she has a higher chance of dropping out of university. Edwards [3] stated that students from Australia and Japan are more likely to complete their courses when there is a strong relationship between the students and their teachers. These reasons can be understood by Ryan and Deci's [4] "Self Determination Theory" (SDT), which outlines three psychological needs that determine motivation: autonomy, competence and relatedness. Autonomy is the need for students to feel in control of their own life, competence is the ability of the student to master their learning and tasks and relatedness describes the student's need to feel connected to and cared by the people around them.

With the new teaching and learning methods, e.g. blended learning [5, 6], innovation assessments [7], it is expected that students will feel more motivated in the university; however, first year students may not experience many new learning methods.

II. Materials and Methods

An informal survey consisting of 20 questions was formulated to assess students' first year experiences in the universities located in Sydney, Australia. These questions are related to motivation and other relevant aspects of students who attend a university in Sydney. The survey was sent out as a Google Form to students currently in their first and second year of the university. Only 18 students responded to this informal survey. We examine the responses of each question (in the results and discussion section) individually and then provide an analysis of the responses as a whole.

III. Results and Discussion

In relation to Question 1 (Which of the following reasons contributed to your decision to study at your current university of choice?), the main reason (72%) students chose their universities was due to the university being recommended by their friends, family or former students of the university. Alternative reasons students chose their current university were due to the university being one of the top ranked universities of Australia (50%), several of their friends attended the university (44%) or the university was close to their home (22%).

In relation to Question 2 (Is transport to your university problematic for you?), about 33% of the responders believed

that transport to their specific university is a problematic issue for them, 39% of students answered "no" and 28% of responders were "neutral" on the topic.

In relation to Question 3 (How would you describe your time management in the first few weeks of university?), the majority of students (56%) mentioned that their time management in their first semester had been "good" and they were on time for most classes. The next 28% of students admitted they had "bad time management" causing them to miss several classes and 11% of students stated that their time management had been "horrible" where they were extremely late to university and missed many classes.

With respect to Question 4 (How would you spend the majority of your free time/breaks at university?), about 56% of the students surveyed spent the majority of their free time/breaks at university by quietly studying individually, 28% of them spent their time on their phone and social media while 11% spent it talking to friends on their university campus. In relation to Question 5 (Have you had significant tutoring support during high school?), a significant proportion of responders (72%) answered that they had tutoring support, 22% said they rarely went for tutoring and 6% responded they never went for tutoring.

In relation to Question 6 (What was the study load you chose for your first semester?), about 67% of students studied full time and 33% of students studied part time. With respect to Question 7 (Did you have difficulty accessing the online content for your university courses?), majority of the students (67%) admitted that they had difficulties in accessing the online content for their university courses while the remaining 33% did not find this to be a significant issue. In relation to Question 8 (Are you part of any of the societies or clubs in your university?), majority of the responders (over 50%) stated that they were not part of any society.

In relation to Question 9 (How do you find the social density of your university?), about 83% of the students surveyed believed that the university which they studied in has an average social density. The remaining students (17%) found the social density to be very crowded. With respect to Question 10 (Compared to school, do you feel like your teacher care about you in university?) 50% of students were neutral towards the issue, 38% thought their school teachers were more caring towards them and 11% thought their university teachers were more caring than their high school teachers. Regarding Question 11 (Do you think the amount of freedom in university, as compared to school has affected your first semester results?), about 89% of students admitted that the amount of freedom in university, as compared to school, has affected their first semester results. The remaining 11% stated that the freedom had somewhat affected their results.

In relation to Question 12 (Do you support the idea that Year 12 students in school should be given some lesson on how university operates as compared to school?),100% of the responders said "yes". With respect to Question 13 (What do you like the most about university?" a short response question was given to the students to list their responses. About 28 of the students stated that the freedom they experience in university is the main reason they like university. Other responses included that university had a better environment than school, there was more space, new people and that the university was close to them. A small minority mentioned that they liked "nothing" about the university. In relation to Question 14 (What do you dislike the most about university?" a short response was also given for students to list their responses. Categorising the 8 responses, majority (62%) of the students disliked the work, i.e. the workload or difficulty. One of the answers included students disliking the location of their university, there being little effort to help students and one student disliked everything about the university.

With respect to Question 15 (Do you feel that a university degree is valuable and necessary for success?), about 44% of the students believed that a university degree is "valuable and necessary for success", about 17% of responders believed the "opposite", while the remaining 39% of students said they somewhat believed that a university degree is important for success. In relation to Question 16 (Do you think the university subjects are too hard, compared to high school?), about 72% of the students admitted that university subjects are "harder" than high school subjects, 11% of the students did not agree and 18% of the students said university subjects were somewhat harder than school.

With respect to Question 17 (Do you skip lectures to do other things e.g. sleep, work, and hang out with friends?), about 56% of students answered "yes" and 44% of students answered "no". In relation to Question 18 (Have you found it difficult to make friends in university?), about 44% of the students found it "kind of difficult" to build new friendships at university, 39% admitted to struggle finding friends, while 17% had no issue with this.

In relation to Question 19 (How many times did you use a medical certificate in your first semester of university to avoid academic penalty?" about 56% of the students mentioned "they did not use a medical certificate" in their first semester to avoid an academic penalty, 28% of students used a medical certificate once, 11% used it twice and 5% used a medical certificate more than twice. Finally, in relation to Question 20 (When do you usually submit your assignment?", about 50% of the students said they usually submit their assignment "on the day it is due", 28% of students said they send their assignment "a few days before it is due", while the remaining 22% said they submit their assignments 0-60 minutes before the assignment is due.

Motivation is a known factor contributing to student dropout rates [4]. The survey questions can be divided into the three "psychological needs of motivation" according to the SDT. Questions 11, 13 and 15 are linked to the psychological need of autonomy. University is a time of life where great autonomy exists, e.g. in the course choices, timetable choices, little accountability with regards to class attendance etc. Question 15 asked students if they believed a university degree to be valuable and necessary for success. It is important for students to value their university degree in order for them to find their university work relevant and important, and therefore allow them to take ownership of their university work. It is thought that students who do not value their university degree would be more likely to drop out of university. Question 13

asked what students liked about university and the most common answer given was "freedom." Freedom is an important aspect contributing to autonomy and therefore the amount of freedom would increase student motivation in university.

Question 11 asks whether the level of freedom in university, as compared to school, affected their first semester results. Although 89% of the students responded "yes" to this question, it is difficult to analyse the impact of freedom on student performance at university as the question does not specify whether the effect of freedom in university was positive or negative. It could be hypothesised that the increased level of freedom allows students to feel greater autonomy and therefore there is a positive increase in their results. However, it could also by hypothesised that the increased level of freedom in the university compared to high school negatively affects student performance as they are incapable of managing their time and effort without stricter boundaries to extrinsically motivate them.

Questions 5, 7, 12, 14 and 16 are linked to the "psychological need of competence". If work is too difficult for students, there is evidence of a decrease in student motivation [4]. The survey responses indicate that students are facing a certain level of difficulty in university e.g. 67% of students have had difficulty in accessing the online content of their university courses, 72% of students believe university subjects are "too hard" compared to high school and when students were asked what they disliked about university in Question 14, 63% of students listed the "workload" or difficulty of work. The responses indicate that students could possibly be suffering from a lack of motivation due to feeling incompetent in their studies. The responses to Question 5 show that 72% of students had significant tutoring support for some of their subjects and this could be a possible factor for why students are struggling with the independent study nature that university requires due to their reliance on tutors and external help during high school. It could be beneficial to provide year 12 students with a course outlining the manner in which universities operate in order to create students who feel more prepared and competent when they first enter university – 100% of the responders felt like "such a course should be provided".

Questions 1, 4, 8, 10 and 18 explore the "psychological need of relatedness". A university operates on a different structure than a school and it is easy to see how the nature of university could potentially leave students feeling "isolated" e.g. in university, students are not in the same cohort of classes as consistently as they are in schools, they are one student within hundreds in a class etc. Question 1 shows that a large proportion (44%) of students chose their university based on the fact that their friends were attending the same university. During breaktimes, 11% of students spend their time talking to friends and 33% of the students are part of student clubs. These factors are important for students to feel connected to their environment of learning. However, the responses show that majority of the students do not spend time with their friends during breaks and that majority of the students are not part of a student club. Furthermore, 39% of the responders stated that it was difficult for them to make friends in university, and a further 44% of students acknowledged that it was somewhat difficult to make friends at university. Finally, from Question 10, it can be seen that only 11% of students feel like their university teachers care about them, while 50% of the students feel like their school teachers cared more about them and the remaining 39% feel as if their university teachers care about them to a limited extent. It could be that students in university feel disconnected from their peers and teachers, contributing to low motivation that could eventually cause them to leave university.

This research could be improved in the future by surveying a larger sample size and ensuring that students from a wide range of universities are surveyed. Furthermore, including students who have already dropped out of university would provide valuable data to be analysed.

IV. Conclusion

This paper examines some common issues faced by the first year university students in Sydney, Australia. It has been found that many university students see a big difference between the high school and university in terms of "academic freedom" and "care and support". The university dropout rate seems to be linked with these factors. All the participant students agreed that in their year 12, a course should be offered to them on university teaching and learning style. Further study is recommended (with bigger sample size) to confirm the findings of this preliminary study.

Acknowledgment

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Art of teaching biostatistics – a case study from Monash University

Baki Billah

School of Public Health and Preventive Medicine, Faculty of Medicine, Nursing and Health Sciences; Monash University
Melbourne, Australia
baki.billah@monash.edu

***Abstract*—Biostatistics units are designed to introduce students to biostatistics, which is the science of describing, summarising, and analysing health-related data. It is essential to understand biostatistics in order to design, conduct, and interpret health-related and other research outputs. Biostatistics units at the School of Public Health in Monash University are offered as weekly face-to-face lectures, block days and online learning modules. However, teaching biostatistics remains always challenging due to lack of prerequisite knowledge. The author has over the years introduced several teaching innovations which have had a great impact in enhancing student learning in this unit. The aim of this paper is to highlight some key aspects of bistatistics teaching that could make this learning interesting, interactive, and engaged. The methodology can be applied to other similar subjects in mathematics, science and engineering.**

Keywords—biostatistics, learning and teaching, online learning

I. Introduction

Knowledge of biostatistics is essential for all public health practitioners [1] Teaching of biostatistics is a challenging task as many of the enrolled students come from biological sciences background who have not adequate mathematical background. Many students often see biostatistics as a requirement that simply must be completed, and it is approached with apprehension [2].

This paper presents the experience of the author in teaching biostatistics in Monash University, Australia. He has over the years introduced, for the first time at the school, several teaching innovations which have had a great impact in enhancing student learning. The aim of this paper is to highlight some key aspects of bistatistics teaching that could make this learning interesting, interactive, and engaged. The techniques can also be applied to other relevant fields such as teaching statistics to engineering students.

II. Methodology

A range of approaches, such as flipped classroom and workshop style lectures, were applied to 1,500 postgraduate on-campus as well as online students from 2016 to 2019 who enrolled to Masters in public health or PhD in public health in Monash University. Resources/technologies such as e-book and audio-videos were adopted.

E-book – biostatistics: The author has developed e-book for all postgraduate core and undergraduate core/optional units at the School of Public Health, Monash University. The books are available via moodle site of the respective units. Students were able to conveniently access, portion and follow structured learning offered through e-books. Students report an enhanced learning experience from having such learning materials available in e-book format.

Audio-video – biostatistics: The author has developed audio-videos for key concepts of biostatistics. Audio-videos that cover the week's learning material are located on the allocated Moodle site. On campus and block day students are expected to watch the related audio-video before attending the lecture prepared to engage in deeper learning through group activities that are designed to enhance their knowledge and skills. Fully online students are recommended to watch the videos before attending the ZOOM online tutorial and attempting the Moodle Class Activities. Student learning experience is enhanced by benefits of a flipped class-room approach [3]. Having an overview of the topic being discussed for the week prior to attending classes places students in a unique advantage to benefit from a deeper and more enriching learning experience. Our concept videos, which are compatible on a multitude of platforms that include PC, mobile and tablets were greatly appreciated by students.

E-book – SPSS statistical software package: Biostatistics is complemented with statistical data analysis software package. The author has written step-by-step instructions manual for the statistical software package IBM SPSS and developed audio-video for all contents in the manual. The SPSS instructions manual alongside the audio-video follow throughs are highly appreciated by students. Having access to such easy to follow and aligned resources to the learning outcomes help make learning statistical analysis learning on a software platform enriching and relevant.

Audio-video – SPSS statistical software package: Students are provided with support through audio-visual training in statistical software package IBM SPSS. A total of 27 videos have been created. These audio-videos provide step-by-step demonstration on how to perform data analysis using each of the statistical methods that are covered in this unit. These high-quality audio-videos are greatly appreciated by students (as reflected by very high student feedback reports). Having access to such easy to follow and well-aligned resources help make learning statistical analysis learning on a software platform less intimidating. This provides a supportive learning environment for our students.

Flipped Classroom: The author uses a flip classroom approach to reverse the timing of learning and lecturers. This learning strategy places students at the centre of their learning and leads to a deeper construction of knowledge and skills of biostatistics. The flipped classroom approach allowed for the students to become exposed to the topic to be discussed in class prior to attending it. This resulted in a deeper student understanding of the subject matter. This was best implemented by use of short concept videos that were developed on Articulate Storyline 2.

Workshop Style Lecture: Further engagement with the students is provided through individual or group activities during weekly lectures, block days lectures, weekly/online tutorials and online activities. These activities help students to learn statistical theories and its application side by side. Students found this avenue to complete, discuss and receive feedback regarding topic related activities to greatly help consolidate their learning on a consistent basis.

Technology Use

Mentimeter: The author has also introduced Mentimeter in lecture/tutorial. This interactive multimedia presentation tool was used to help students review important topics on a weekly basis through quiz style questions. Students found this approach to be especially fun and engaging, and turned out to be a great hit with our students. It enriched the biostatistics student learning experience vastly.

Webinar (ZOOM) tutorial: Personal contact and support are considered critical to the success of biostatistics units, so the author further support the off campus (distance and online) students with real time tutorial support through an easy to use Webinar (ZOOM) tutorial. The author is the first at the School of Public Health and Preventive Medicine, Monash University, to introduce ZOOM online live tutorial for distance as well as online postgraduate students including Pearson Monash-Alliance biostatistics unit. These Zoom tutorials have proven to be a crucial and popular resource for the distance/online students who juggle busy work-study schedules. Live tutorials provide these students valuable time with course instructors/tutors where they can clarify concepts being learnt. This resource has truly enriched the distance/online student learning experience within the School's Masters in public health program.

Articulate Story Line/Camtasia: Articulate Story Line is an e-learning software which helps in to deliver interactive courses to learners on any device and to build interactions, assessments, decision-making activities, and many more/Camtasia is useful to create engaging videos for the students, especially for online students.

Using the flipped classroom approach, workshop-style lectures as well as technology-assisted learning, my classes are well known to be highly engaging and effective amongst students and peers, see the number of views (for six deliveries) presented in the following figure.

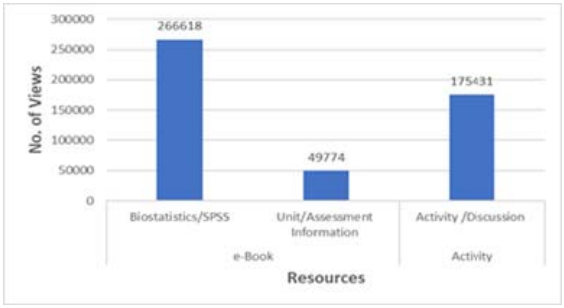

Fig 1: No. of views of the resources and participation in online formative activities/assessments.

Effectiveness

The teaching innovations, presented here, have a great impact on student learning experiences in the School, which is evident by the success rate, e.g. the overall passing rate of all biostatistics units is 96.7% (Fig 2). Both quantitative and qualitative unit evaluation for the units coordinated by the author recognised how students found these to be an effective way for students to review and stay engaged with the unit's subject matter throughout the semester (Figs 3 & 4). The biostatistics subjects, coordinated by the author have been classified as the "Golden Category" at Monash University for a consecutive four-year period from 2016 to 2019 by achieving evaluation scores between 4.75 and 4.92 out of 5.

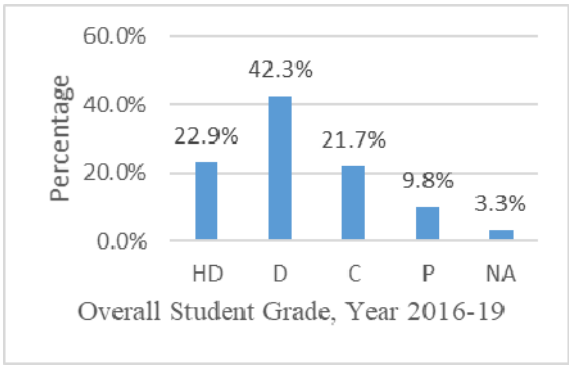

Fig 2: Distribution of grade for teaching year 2016-2019

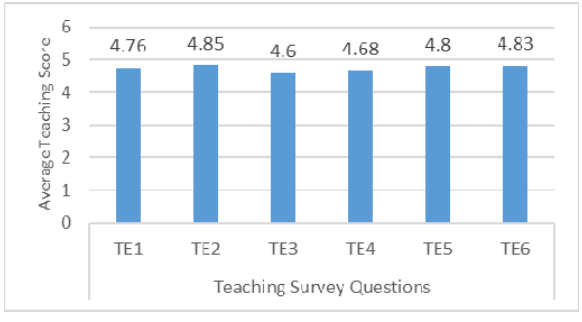

Fig 3: Teaching evaluation score from 2016-2019, see below for details of survey questions.

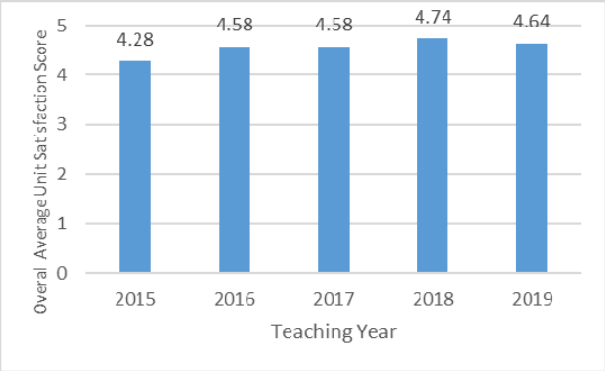

Fig 4: Overall average evaluation score from 2015-2019, see below for details of survey questions.

Teaching Survey Questions:

TE1: Billah was well prepared.

TE2: Billah was enthusiastic in the way he presented the unit.

TE3: Billah was clear in his explanation.

TE4: Billah provided useful feedback to students.

TE5: Billah provided opportunities for interaction.

TE6: Overall, I was satisfied with Billah's teaching.

Unit Satisfaction Evaluation Question: Overall, I was satisfied with the quality of this unit.

III. Conclusion

An innovative teaching method is presented here for biostatistics unit in Monash University. The method involves various blended learning approaches such as e-books, audio-video and face-to-face sessions. The developed teaching innovations have a great impact on student learning experience. This methodology can be applied to other units/subjects in relevant fields such as mathematics, science and engineering.

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Girls in STEM: Building the future

Olivia Mirza
School of Engineering
Western Sydney University
Sydney, Australia
o.mirza@westernsydney.edu.au

Deslie Jameson
Parramatta West Public School,
Sydney, Australia
Deslie.Jameson@det.nsw.edu.au

Alicja Knedl
Parramatta West Public School,
Sydney, Australia
alicja.knedl@det.nsw.edu.au

Abstract*— The complexities of today's world require all to be equipped with a new set of core knowledge and skills to solve difficult problems, gather information, evaluate evidence, and make sense of information they receive from varied print and, increasingly, digital media. The learning and doing of STEM helps to develop these skills and prepare students for a life experience where success results not just from what one knows, but what one is able to do with that knowledge. Thus, a strong STEM education is becoming increasingly recognise as a key driver of opportunity, and data shows the need for STEM knowledge and skills will grow and continue into the future. Those students who have practical and relevant STEM precepts embedded into their educational experiences will be in high demand in all job sectors. This paper studies the influence of STEM education on primary school girls in their early education.

Keywords*— STEM, Education, Future.

I. Introduction

Sanders and Binderup [1] explained that traditional schooling segregates the concepts of Science, Technology, Engineering, and Mathematics (STEM) teaches them separately as discrete subjects. However, STEM does not follow the suit. Rather, it focuses on converging the subjects and teaching them via real-world applications. The STEM curriculum works by exposing individuals to opportunities where they can solve real-life situations, smoothening the learning process.

The world, today, revolves around the concepts devised by STEM. The four disciplines have become intensely involved in every nook and cranny of our lives. It is due to this that propagating STEM knowledge has become a necessity. However, teaching the concepts via traditional means is sure to be futile. Pearson and Young [2] suggested that a specialised curriculum must be emphasised to facilitate institutions to build a solid foundation for future generation. Furthermore, it mentally builds them up for active participation.

Historically, we have been constantly told that boys are better at sciences and math. Conversely, girls have been constantly showered in the stereotypical mentality that they are more suited to arts' subjects. Therefore, it isn't surprising that girls have a meagre representation in the science and math circles.

Herschbach [3] surveyed that women make up only ¼ of the entire STEM workforce around the world. Contrarily, women dominate men when it comes a STEM degree. Further statistics show that women constitute 15% of the engineering force and 25% of the computer and mathematical sciences. In Australia, women made up 27% of the STEM workforce in 2016.

There are various reasons for such a meagre constitution of women in STEM. The prime reason is the lack of practical experiences. Women have been quoted saying that they love STEM activities but the lack of practical exercises discouraged them from building a career in the field.

Studies by Vomert et.al [4] stated that women are still treated secondary in many countries. That needs to be a balance and all women should get equal opportunity. This can be achieved only when they are educated. So there is a special emphasis on STEM for girls. Also, this movement will let women to understand their everyday science clearly and they can enjoy all the work they do at home or outside.

According to OCS [5], there are numerous prominent Australian STEM organisations and programs across the country, currently working to raise the profile of STEM. The organisations involved in Australia range from government, STEM industry (including organisations and businesses that rely on STEM skills and expertise to produce products or provide services), research organisations (that rely STEM expertise to innovate), learned academies, educators (from early years to tertiary education), and STEM professional organisations, groups and associations (for profit and not-for-profit that promote engagement and communicate the importance of STEM). As an example of the breadth of STEM activity, the Australian Chief Scientist's 2016 STEM Programme Index outlines over 250 active STEM programs across the country, provided by businesses, universities, science and education agencies, and government, OCS [6].

However, Australia is not producing enough people with STEM skills to meet the growing demand. Part of the problem lies with the STEM pipeline: the number of young Australians choosing STEM subjects in high school is in decline. Australia is also slipping down the international league tables when it comes to literacy in maths and science OECD [7].

On top of this, Frieze and Quesenberry [8] showed that there's a significant gender disparity in STEM in Australia, with females significantly underrepresented in STEM education and careers. Unless Australia can address both the mismatch between increasing demand and falling supply, and the gender imbalance, businesses and institutions will face a significant shortfall of appropriately skilled and diverse workers, which in turn will have consequences for our future prosperity and growth.

The vision for Australia must include an education system that expects and achieves a high level of student achievement, mastery, enjoyment and innovation in STEM, year after year – through well resourced, knowledgeable, inspiring and passionate teams of teachers and practitioners.

In order to fulfil the vision, the first step to moving up the ladder is to start with little kids. Studies by Porefeli et al. [9] have emphasised the critical need to promote career options to young children during their primary school years. They recommend a process of career exploration so that children can develop positive orientations to the world of work. These can help to close the gender gap in science achievements right from a young age and this understanding keeps growing till kids move on into high school at the age of 13. Therefore CSIRO Education and school joint collaboration to start STEM activities right from preschool. Let them accept the way of learning. They will be so glad to make their hands dirty while studying. This paper conducts a survey about girls in STEM from primary schools with regards to its importance. This paper investigates what can we do to engage young people, particularly girls, in STEM education?

II. Survey for Students

TABLE 1. Survey distributed to students

Knowledge/Experience from STEM Group	
1.	Do you enjoy Mathematics?
2.	Would you recommend Girls in STEM to other girls?
3.	Choose three activities you enjoyed so far
4.	What have you learnt so far at the Girls in STEM Group? Give a thoughtful, detailed response
Perception towards STEM	
5.	Has your attitude to STEM changed by being part of this group? How?
6.	Which STEM experience you like most? Why?
7.	Have you involved in any extra curriculum STEM activities at school or outside of school?
8.	What are the extra activities?
9.	What other thing would you like to do in the Girls in STEM group?
Pursue STEM in Higher Education	
10.	Do you think you will choose to student STEM subject in high school?
11.	Are you interested in following your interest in STEM in the future? What would you like to pursue?

The survey issued for students consists of only 11 short answer questions to get a genuine response from students. Questions were also kept short and used simple questions requiring either 'Yes' or 'No' or "Unsure" as the answer and descriptive questions were included requiring them to demonstrate the reason for selecting their answer. In this study, the survey delivered to 30 students aimed to get feedback on student perceptions about three areas: (i) Knowledge/Experience from STEM Group, (ii) Perception towards STEM and (iii) Pursue STEM in Higher Education, as shown in Table 1.

III. Survey's Results and Discussion

Early Education can play a key role in connecting young people with future pathways, including employment in STEM. It also plays a crucial role in connecting and communicating with key influencers of young people, including their families, which can play a pivotal role in changing perceptions about STEM on a broader scale. It was identified through the survey mentioned above that primary education plays an important role in changing the culture of STEM, promote STEM engagement and participation and raise the profile of STEM.

This survey was undertaken in the duration of a year with 28 selected girls from year 3 to year 6 to participate in Girls in STEM at Parramatta West Public School. The duration of this engagement is one year. The school participated in five different STEM activities. The activities included discovering fossils and investigating rocks with a geologist, building bridges using straw with bridge engineer, learning about tech ology with Google educator, learning about genetics and extracting DNA with Gene researcher and learning about how humans think and feel with a psychologist. Details of the survey will be discussed in the later section.

Knowledge/Experience from STEM Group

Connecting with real world experiences that make an impact and diverse female experts for support and inspiration, can provide girls with authentic STEM connections and opportunities that promote sustained engagement.

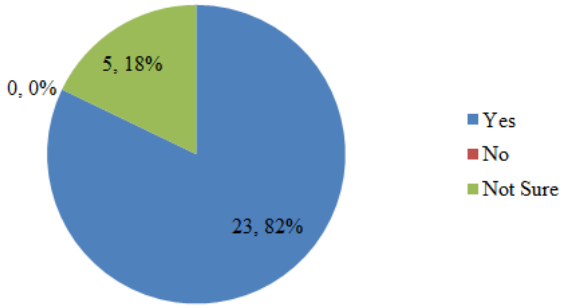

FIGURE 1. Survey result for Questions 1 and 2

The survey for Questions 1 and 2 show similar result as shown in Figure 1. 82% stated that they enjoy Mathematics and would highly recommend the STEM program to other girls.

Throughout the one year program, the STEM girls were exposed to different type of STEM activities. In this survey, they were asked to choose top three of the activities. The activities include:

1. Discovering fossil and rocks
2. Bridge Building
3. Learning about DNA
4. Learning about technology education, Google
5. Learning about psychology

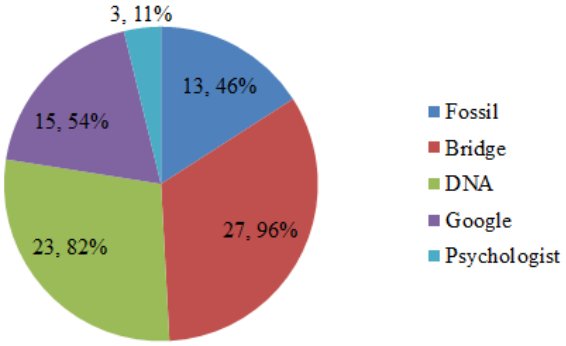

FIGURE 2. SURVEY RESULT FOR TOP THREE ACTIVITIES

From Figure 2, it showed that the most picked activities are bridge building, followed by DNA. This is due to these two activities is interactive activities where the student need to build a bridge and apply their daily activities related to DNA. Interactive activities engaged students in a number of ways; in particular, they prompt students to engage with content, rather than passively absorb it. Question 4 also reflects the Question 3 where most of the students are excited with the interactive activities.

Perception towards STEM

From this STEM program, the authors herein wanted to observe the change in the girls' perception towards STEM. After the completion of STEM program, the girls' attitudes and confidence in STEM areas improved. This is shown in Questions 5 and 6. At the same time, the survey also considering the strategies that encourage their long-term interest in STEM areas. Among other findings, the main discovery of this survey was that a direct connection exists between the visitor's own interests and excitement that makes STEM curriculum more meaningful for girls. The culture of the school environment supports achievement and helps the girls feel more involved within the school environment, especially in the formation of 21st century learning skills.

Survey from Questions 6-8 shows that only 18% of the girls have extra STEM activities at school. Extra STEM activities will positively alter the girls with regards to how STEM relates to society, and to them. Students involved in extra-curricular STEM activities have an increased capacity to understand STEM activities, with a distinct rise in curiosity, ability, and awareness. Additionally, students who take part in STEM extra-curricular activities reach higher levels of education, and are more likely to have a career within the field. Therefore, from the survey, this shortfall needs to be improved in the future.

Another key activity of this program also included the creation of meaningful STEM curriculum experiences. Survey from Question 9, the authors herein observed the girls asked for more activities that linked curriculum to real world concepts, context and opportunities that allowed students to make a real-world impact and explore their passions and interests.

Pursue STEM in Higher Education

STEM curriculum implementation in Parramatta West Public School empowered students through choice, skill development and allows students to realise real world applications of STEM. These effective messaging can attract girls to consider STEM and help girls to envision themselves as STEM high school to their professionals life, as well as help to support their key influencers. From Questions 10 and 11, 75% of them will pursue STEM subjects in high school, 3% are not sure whilst 22% no response. This is a good outcome as STEM education helps to bridge the ethnic and gender gaps sometimes found in math and science fields. Initiatives have been established to increase the roles of women and minorities in STEM-related fields. STEM education breaks the traditional gender roles. In order to compete in a global economy, STEM education and careers must be a national priority.

IV. CONCLUSION

"Girls and STEM" is a key phrase in education. It is relevant, meaningful, and significant. With the large number of recent research studies focusing on STEM, it was a crucial time to conduct this study and further studies on girls and STEM in Parramatta West Public School. Parramatta West Public School found to promote and encourage girls and STEM. It is a place where collaboration skills are learned and experienced in a safe and supportive environment. From this research herein, the authors conclude that:

1. STEM is not simply a description for the combination of subjects; it is a much more complex idea and as such requires strategic and coordinated action.

2. Engaging and sustaining young people in a lifelong journey in STEM requires a different type of approach. It requires students being active participants in learning.

3. Educators, industry, mentors and volunteers are the facilitators and enablers on this journey, and young people are the enactors, taking control and collaborating with others to solve real-life problems.

4. This type of approach reflects the way STEM industry works, develops key 21st century skills in young people and connects them with relevant experiences to enable them to be well prepared to embrace a future in STEM.

V. ACKNOWLEDGMENT

Authors would like to acknowledge the students who took part in the informal survey, the teachers from Parramatta West Public School and the Western Sydney University (publicly available materials have been used from these universities in preparing this paper).

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Addressing The Future Imbalance Of Gender Diversity In Engineering Caused By Misconception: Observations Of A Female Millennial Engineer In The Civil Space

Adriana C. Assey
Lendlease
Sydney, Australia
adriana.assey@lendlease.com

Abstract
With the rise of companies adopting an equal ratio of female to male engineers to combat the existing 30:70 ratio in the industry, it is fundamental to capture the experiences and change in trends being instituted by millennials, particularly; females in engineering. Although diversity is now more than ever being heavily piloted by tier one firms such as Lendlease, it is important to capture the experiences of female engineers and to relay this through the education system to combat the fall of nearly 3% of female engineering graduates between 2018-2019 according to Engineers Australia. The shrinking number of female engineering graduates may be attributed to a lack of understanding of the expectations of the profession and societal attitudes which have transgressed to younger generations. This paper endeavours to relay the observations of a newly graduated female civil engineer currently working in the construction field. Experiences of female and male peers have also been accounted for anonymously in the composition of this paper. It is the endeavour that the observations of this paper will act as a guide for those in the education sector; especially secondary and tertiary levels to illustrate a clearer picture of the expectation and roles of females in a historically male dominated industry.

Keywords: **Diversity, Equality, STEM, Engineering**

I. Introduction

The observations of newly graduated female engineers in the civil space is crucial to consider in the education system when advocating for gender equality. In a report released by Engineers Australia in 2019, it has been noted that a fall of 3% of female engineering graduates has occurred between 2018 to 2019 [1]. This compares poorly with male graduates which conversely increased by 4% in the same period. Although there a multitude of reasons to which this may be attributed, it is the stance of this paper that this is the result of a societal attitude which has misfed 'overt and unconscious bias' [2] into the education system.

Many tier one firms such as Lendlease have endeavoured to address the current 30:70 imbalance in the workplace [1] by adopting a 50:50 ratio of females to males in their 2019 graduate program. In order to achieve gender equality in engineering it is important to understand the current gender balance or lack thereof existing in the industry and being released from the education sector. In addition, it is critical to note both the positive and negative observations and experiences of newly graduated and established engineers to provide a holistic picture to prospective engineers.

II. The Education system

The following sections herein endeavours to elucidate the position of the education system with respect to the promotion of engineering among prospective female engineers from the earliest stage of their career; their education. Highlighted in this section are the misconceptions and attitudes that have yet to be addressed adequately by the education system which is deeply rooted in societal attitudes.

Elementary to Secondary Schooling

The education system is foremost instrumental in the 'production' of female engineers. Through formal education, one's attitudes towards Science, Technology, Engineering and Mathematics (STEM) are formulated. From primary to tertiary education, this is where the growth of engineers takes place. Although an interest in mathematics and science is purely individual interest, the focus on these subjects; more so their application is lacking in the education space. Children in early 2000's experienced a curriculum focus predominantly on the content within each subject with lesser focus on usefulness and application. As a consequence, few millennials especially women have opted for engineering, choosing to dedicate their working life to fields such as business, allied health and creative arts. Though crucial to the makeup of society, the minority of female engineers across all sectors could be adequately addressed with a greater focus on the usefulness of science and mathematics.

The Australian government has recognised the importance of STEM promotion in early schooling with $64 million dedicated to fund early learning and school STEM initiatives under the Inspiring all Australians in Digital Literacy and STEM measure [3]. However, this comes at a time where according to a government funded study, 70% of male year 9-10 students are taking at least one STEM subject which is contrasted to approximately 30% of females [4]. This finding parallels to a comparison of male-female interest in engineering also revealed in the study which demonstrated a difference of 55% and 28%, respectively [4]. The aforementioned government study noted that there is a lack of understanding of what engineering entails by citing the feedback of a female student surveyed as part of the

research. A male student in the same study was also quoted as not seeing the usefulness of Engineering and STEM related skills in other professions. The study therefore highlights an area where the education system can improve in terms of conveying what engineering comprises and transferrable skills associated with the profession and a study of STEM subjects.

Ultimately the result of the lack of information of what engineering entails especially among females is a lack of confidence in achieving success in this field. This is supported by a government funded study conducted in 2019 [5] which compares confidence levels of theory based subjects such as science to the more heavily application based engineering as captured in **Error! Reference source not found.**.

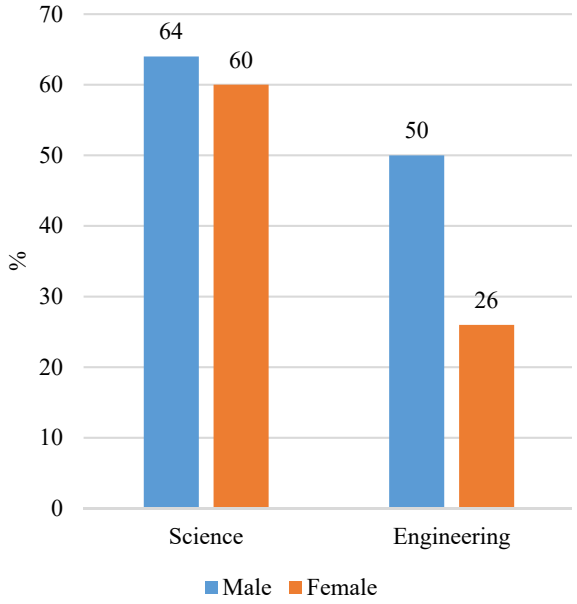

Figure 1 Confidence in achieving good results in Science and Engineering[5]

Error! Reference source not found. showed is a greater confidence among students for theory based STEM subjects such as science as opposed to engineering which is application based by comparison. Also shown by **Error! Reference source not found.**, is a stark contrast in confidence levels between males and females in studying engineering as a subject. The lack of understanding of what constitutes engineering among females may be causative of this result.

The misconception of engineering among students was similarly corroborated in a study of elementary students which revealed a masculine conception of engineering. The study [5] revealed that students associated an engineer with historically masculine professions such as labourers, mechanics and technicians. Little understanding of the interrelation between theory and application that the engineering profession entails has been demonstrated by students with the predominant masculine conception based on a lack of understanding of the current gender neutral acceptance in modern engineering [5-9].

As discussed, the current position of the education system with regards to the understanding of engineering among students –in particular; female- has been elucidated. By understanding existing conceptions of engineering among female students, government initiatives may be effectively used to help address the gender imbalance in engineering from the earliest stage of the development future engineers; early education.

Tertiary Education System

The misconceptions of engineering from elementary and secondary schooling appears to transcend into the tertiary education system. By tertiary level it is the expectation that most female students have developed an affinity for STEM subjects and more so, its application. However, the misconception of the lack of interrelation between theory and practice within engineering is apparent with many students either not anticipating the level of theory associated with the study of engineering at tertiary level or conversely the extent to which various mathematical and scientific concepts work simultaneously to be applied in practice to a real world challenge. This, combined with an outdated curriculum which is not a true reflection of the knowledge and skills required in the industry and some instructors lacking in industry experience exacerbate the depleting number of female engineers which is reflected by student attrition rates.

Understanding tertiary student attrition in engineering is key to elucidating why the output of female engineers is lower than male counterparts. Some of the largest factors underpinned by several studies include classroom climate, conceptual understanding, achievement pressure, self-efficacy and self-confidence, high school preparation, interest and changes in career goals [10]. Although each factor is not gender specific, it is critical to understand that certain factors may be more likely to affect a specific gender more than the other. In addition, many of the aforementioned factors are a culmination of elementary and secondary education experience. Engineering is a naturally competitive environment at a tertiary level and heavily encourages independent learning and initiative. This generates two major responses from students; to persist and work with fellow peers, or isolation until problems become exacerbated by a lack of a strong conceptual knowledge. In an engineering classroom climate where women are typically a minority, are ‘differentially socialized’ to respond to competition, the structure of teaching and advising than male counterparts [10]. Millennials and in particular females were more likely to respond to a more engaged academic climate than an impersonal structure of teaching with a lack of guidance [11]. In the engineering industry, success is only earned through teamwork and a clear understanding of scope and requirements. Although independent learning is critical to one’s development as a professional engineer, proper guidelines to provide a clear understanding of scope with adequate access to instructors who also understand the guidelines they have set is fundamental to retaining prospective engineers, both female and male.

Further supporting that classroom climate heavily affects female engineering attrition at university is the study conducted by Geisinger and Raman [10] which highlighted that different colleges demonstrate different

rates of female engineering attrition. It was suggested by Geisinger and Raman [10] that even when females had the same or higher level of education prior to university, some colleges retained a female engineering candidature better than others citing different departmental and engineering cultures. Overt sexism in some departments and gender specific university atmospheres was causative to a lack of retention of female candidates [10, 12, 13]. Geisinger and Raman [10] made several suggestions in order to address this culture including; sensitivity training for faculty, initially creating group work scenarios where groups of women work together in first year to build confidence and hiring and retaining a larger number of women faculty members.

Lack of high school preparation and the resultant low self-confidence when students encounter engineering at a tertiary level is a critical aspect to address when looking to address the attrition of female engineers at a tertiary level. Geisinger and Raman [10] reported that a large number of students who left engineering were typically accustomed to being at the top of their classes at a secondary level and their grades upon entering engineering were not meeting their expectations. This may be addressed through a greater promotion of preliminary courses before university or a greater incorporation of tertiary engineering concepts at a secondary level. Many universities in Australia do offer preliminary courses, however, often this only caters for students who have already decided their career path. A more fitting program would be to offer these courses to secondary education to provide a better understanding of the level of engineering study to expect at university and to develop a strong conceptual understanding that many freshmen lack. This would facilitate a greater self confidence among millennials, especially women whereby as substantiated by Rask and Tiefenthaler [14] who reported that the effects of lower grades and persistence were stronger for women as a consequence of innate high expectations of themselves. Thus a greater incorporation of tertiary level engineering coursework into secondary education would highly benefit the engineering education system as a whole and assist in female engineering retention rates.

Another key aspect which is lacking between industry and tertiary education is relevant subjects to the workplace. University excels in teaching graduates theoretical skills with little focus on major industry requirements such as quality assurance. Students typically fixate on the theoretical aspect of engineering, particularly in the first year of study which results in high rates of attrition [10]. The embedment of workplace related subjects such as quality assurance and technical skills into coursework would highly benefit students and retain engineers by diminishing the misconception that engineering predominantly focused on theory rather than practice. Tertiary institutions should reduce the focus on highly theoretical subjects as core subjects which increases attrition [10] and shift the focus to more workplace relevant skills. For example, more students intending to enter the construction field would benefit from quality assurance subjects than final year numerical investigations which, although is at the core of several engineering software, is seldom used explicitly in the industry on a daily basis, yet is still a core subject for final year engineering coursework.

III. Life in the Construction Industry

Upon consultation for this paper, females in the engineering industry typically have a clear understanding of what to expect as a working engineer. There is considerable movement based on the needs and interests of the individual at each phase of life.

Females entering construction typically have clear expectations based on undergraduate experience or research. Many join contractors to follow a common career path projected by many tier one firms as summarised in **Error! Reference source not found.**.

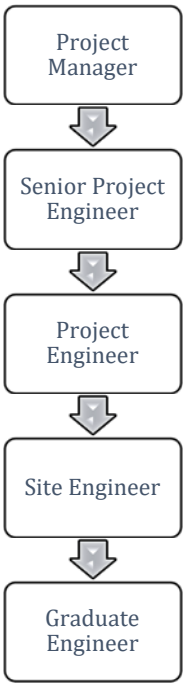

Figure 2 Construction career progression typical of tier one firms

A clear framework of career progression is readily made available, movement between different tiers of engineering/construction companies occurs. This is typified by subcontractors and tier 3 firms where a clear framework is not readily available or established, causing uncertainty and a sense of plateauing early on for a newly graduated engineer. Many engineering graduates seek a clear structure of career progression and remuneration typified by the construction industry which causes millennials to seek employment from tier 1 and tier 2 firms which commonly have structured career programs. The retention of female engineers in the civil space predicated by the sense of security that clear career progression frameworks possess. By adopting clear frameworks many engineering/construction companies will retain a greater number of female engineers provided that career milestones align with the needs and interests of the individual.

In addition to clear frameworks which attracts many female engineering graduates it is also critical to note what factors keep newly graduated female engineers in the construction industry. In the civil space it is very common among millennials whose only experience of construction was through preliminary research or 'word of mouth' to experience a shock when first working in the field. One encounters many character types often unique to the construction space which allows communication skills to be highly developed upon encountering different demographics more common to a construction field than a design space. In consultation for this paper, many millennials do not expect the strength of character and communication skills required, which often results in graduates moving within the civil space to more office based work. In order to combat this shift, it is the recommendation of this paper that universities should allow for more group work situations where students are encouraged to work with unfamiliar people. This forces people and communication skills to be developed at an early stage and is more reflective of the workplace in actuality where choice of colleagues is limited and the cooperation of different demographics and attitudes is expected. This would aid the retention of newly graduated female engineers that lack prior undergraduate construction experience by enabling the development of a stronger and more assertive character more suited to the construction space.

Another means of retaining female engineering graduates in the construction field who lack undergraduate experience would be early and greater exposure to the construction industry [15, 16]. This may be achieved through the provision of site tours hosted by engineering and construction firms. Some new graduates spend minimal time in the field before full time employment and as such have limited knowledge of the different fields available and what to expect [15, 16]. Sydney's boom in infrastructure with major projects such as NorthConnex, WestConnex, Sydney Metro and Western Sydney Airport means that there is an abundance and variety of construction sites available for site tours to be held for educational purposes. Collaboration between the education system and the construction field would enable immersion tours and programs to be developed to provide a clearer understanding of the experiences of a working construction site to prospective engineers. This would enable the construction industry to retain female engineers from a graduate level.

Although the retention of female engineers at the graduate level is critical to addressing the gender balance in the industry, it is critical for the construction industry to acknowledge gender specific issues and prejudice for women at later stages in life. Women in the construction industry tend to face difficulty when seeking start families [17]. The construction field has historically been prejudiced in this matter where often women seeking maternity leave face difficulty adjusting back to work life due to workplace prejudice and a lack of flexibility to accommodate shifting needs especially in instances where the woman is the primary caregiver [17]. Lingard and Lin (2012), also noted that in an attempt to combat inflexibility, females in construction opted for part time work whilst re-entering the industry. Tier one firms have excelled in this aspect offering flexible working arrangements and 'return to work' programs to aid female construction engineers. In situations where women are not able to move to the design or academic space, this is invaluable to retaining female engineers which is where certain tier one firms such as Lendlease, CPB Contractors and John Holland should be commended. This is an area where tier 2 and tier 3 firms should develop in order to retain engineers which extends to the design space across all fields within engineering.

IV. Conclusion

There are a variety of ways in which the gender balance between female and male engineers may be addressed in the engineering industry. The various actions that must take place in order to achieve a gender balance in the engineering industry must occur from the education system at all levels to the industry. By understanding the importance of STEM promotion, early industry exposure, strong conceptual foundations, the practical importance of theory and workplace relevant education, the gender balance may be addressed now to ensure the betterment of tomorrow's engineering workplace for future infrastructure.

V. Acknowledgements

The author would like to thank all anonymous correspondents for their opinions on the engineering education system and life in the industry for the composition of this paper.

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Comparison of Bachelor of Civil Engineering Curriculum of Khulna University of Engineering & Technology and Western Sydney University

Kazi ABM Mohiuddin
Department of Civil Engineering,
Khulna University of Engineering & Technology,
Khulna, Bangladesh
kzmohiuddin@ce.kuet.ac.bd

Ataur Rahman
School of Engineering
Western Sydney University
Sydney, Australia
a.rahman@westernsydney.edu.au

***Abstract*—Civil Engineering education at bachelor degree level emphasizes teaching of students so that they are competent to plan, design and operate real life civil engineering projects. Living a quality life cannot be imagined without a civil engineering solution and innovation in various infrastructure including housing, transportation, air, soil and water, environment, and climate sectors to ensure safety, comfort, sustainability and affordability. Now-a-days, way of life has been changing rapidly due to innovations in IT and allied fields. Students are not satisfied with conventional education systems especially in Bangladesh where existing education system (mainly face-to-face teaching) was implemented and practiced since last 50 years. For this, continuous assessment and improvement of civil engineering curriculum are essential to ensure the knowledge, skills and abilities required for civil engineering graduates in this era of rapid technological advancement and global market demand. This paper discusses the Civil Engineering curriculum of Khulna University of Engineering & Technology (KUET), Bangladesh and compares with Western Sydney University (WSU), Australia based on graduation requirements, course contents, specialization and practical relevance. This paper also presents the similarities and gaps in civil engineering curriculum to explore the opportunities for future improvement in civil engineering education systems considering professional practices and research activities.**

Keywords—Engineering education, civil engineering curriculum, KUET, WSU, professional practice.

I. INTRODUCTION

Engineering education in universities requires to be updated continuously by assessing teaching and learning outcomes fit for rapidly changing world of 21st century and beyond. In Bangladesh, civil engineering education has been provided, in general, like an age-old fashion by which students go through a compact content-rich syllabus in four years. However, an attempt was made recently to convert the teaching-focused into learning-focused education system following Accreditation Board of Engineering and Technology (ABET) accreditation requirements. Civil engineering graduates have to demonstrate achievement of the program outcomes such as engineering knowledge, problem analysis, design/development of solution, investigation, modern tool usage, engineer and society, environment and sustainability, ethics, individual and teamwork, communication, project management and finance, and lifelong learning [1]. Therefore, the existing civil engineering programs in Bangladesh is required to assess to meet the rapidly changing national and global needs.

Quality Assurance (QA) and Quality Control (QC) in engineering education are not negotiable by any means considering the societal responsibility and global mobility of engineering graduates. QA and QC in education depends on nonetheless state-of-art course design, skillset of academic staff, and learning environment. However, very limited attempts on QA and QC in tertiary education sector in Bangladesh have been made till to-date. Course curriculum reflecting the current industry needs is the integral part of the engineering education system, which facilitates graduate employment nationally and globally. However, engineering curriculum in developing countries, especially in Bangladesh, has been lacking in areas such as industry and international linkages and state-of-art facilities for education and research [2].

In this 21st century avoiding professional accreditation of any engineering program is not a desirable option. For this, civil engineering programs in Bangladesh shall be accredited by the professional bodies such as Board of Accreditation for Engineering and Technical Education (BAETE) in Bangladesh. In Australia, undergraduate engineering programs of all the universities are accredited every five years by the Institution of Engineers, Australia (IEAust). The accredited civil engineering program in Australia should meet the competency requirements set by IEAust [3].

Civil Engineers play a vital role in the development of country's infrastructure. They need effective soft skillset to deal with people having diverse backgrounds in addition to the sound technical knowledge. Therefore, teamwork experience having diverse background is required to in the civil engineering curriculum.

According to BAETE, the accreditation of a civil engineering program will enable making students into successful engineers having adequate knowledge, skills and attributes. QA and QC in civil engineering program can be achieved by encouraging healthy competition among different

institutions worldwide. This paper presents the comparison of Civil Engineering Curriculum of Khulna University of Engineering & Technology (KUET), Bangladesh and Western Sydney University (WSU), Australia to ensure that civil engineering graduates especially in Bangladesh acquire the attributes required to meet national standards; and to provide a mechanism for the continual improvement of existing engineering programs.

II. Overview of Civil Engineering Program

Current academic programs in KUET, Bangladesh started in Khulna Engineering College since 1972 and then Bangladesh Institute of Technology-Khulna in 1986 and KUET in 2003. The admission process in KUET, Bangladesh is highly competitive, having an entrance exam on Physics, Chemistry, Mathematics and English for HSC graduates. The admitted students and exam attendees' ratio is about 1:10. Therefore, highly competent students nationwide are admitted in KUET to become an engineer, architect or planner. Civil Engineering is the leading department considering teaching, learning, faculty, research and professional services among sixteen engineering and technological departments in KUET. The curriculum of civil engineering program at KUET is compared with WSU, Australia as it is a highly reputed university worldwide having academic excellence and impact-driven research. WSU has been ranked in the top 251 to 300 band (in the top two per cent of universities worldwide) by the prestigious Times Higher Education World University Rankings 2020 [4]. WSU civil engineering program started about 30 years ago. Table 1 shows the basic overview of civil engineering programs in KUET and WSU.

The civil engineering program at KUET is not yet accredited; however, the process is ongoing to achieve the accreditation from BAETE, Bangladesh. The accreditation culture in Bangladesh is not welcomed in the past because the difficulty to adapt changes. Even in 21st century BAETE, Bangladesh is the provisional member of Washington Accord. The Qualification framework, study timeframe, graduation requirements in KUET and WSU is very similar (Table 1). However, the pre-requisite courses sequence is difficult to maintain in KUET for the back log students which needs to be addressed. The mandatory class attendance is 60% for participating final examination in all theory courses which have weightage of 70% marks. Failing to achieve 60% attendance will treat the course as "Incomplete" and the students have to attend the course later on. However, in WSU civil engineering, students do not meet any attendance requirements in lectures, but lab attendance is mandatory. The inherent requirements in KUET are not defined like WSU. The academic environment in KUET is campus centric, having content based curriculum and limited integration in teaching and research and industry compared with WSU. It should also be noted that most of the KUET students live on campus (in residence halls), but WSU students hardly live on campus student residences. The WSU Bachelor of Civil Engineering has been upgraded to Bachelor of Civil Engineering (Honours) for all students as per current Australian Qualifications Framework (AQF) to meet AQF8 requirements.

TABLE I. Features of Civil Engineering Program

Requirements	KUET	WSU
Qualification Framework level	Tertiary	8 (AQF)
Accreditation body	BAETE (Under process)	Engineers Australia
Study mode	4 years full time, Maximum 7 years	4 years full time /8 years part time
Recommended Sequence	Have provision but not practiced	Yes
Graduation requirements	160 credits	320 credits (Equiv. 140 credits)
Class attendance	60%	Lab Mandatory
Inherent requirements	Not defined	Ethical behaviour No plagiarism Legal Communication Cognition Sensory ability Strength and mobility Sustainable performance
Academic Environment	Campus Centric; Content based curriculum; Limited integration in research and education; Not developed intellectual capital	World reach; Holistic curriculum; Strong integration with research and industry; Developed intellectual capital

III. Syllabus of Civil Engineering Program

The professional work of a civil engineer includes design, construction, and management of buildings, high-rise towers and skyscrapers, bridges, tunnels, water and wastewater treatment plants, airports and harbors, transportation systems, dams and retaining structures and water engineering projects. Considering the wide range of professional activities, Four years civil engineering program (undergraduate) at KUET was designed consisting of eight semesters having five major branches such as structural engineering, geotechnical engineering, water resources engineering, transportation engineering and environmental engineering. The relevant basic science courses such as Chemistry, Physics, and Mathematics are taught at both KUET and WSU (with exception that Chemistry is not taught as a separate subject in WSU civil engineering). The 1st year courses are common for all engineering programs at WSU, and afterwards the students can select their desired engineering program such as Civil Engineering. Similar method was practiced at KUET during 1972 to 1986, which was changed by admitting to a designated engineering program based on merit position of entrance exam.

The 2nd year courses are mostly basic engineering courses which provide the fundamentals of five major branches of civil engineering (Table III). The concept of inclusion all five branches in undergraduate civil engineering program is that the possibility of job opportunity and higher studies in developing countries for civil graduates is likely to increase. However, only two to four technical areas are required for program accreditation. Hence, the breadth of syllabus content at KUET is higher at KUET compared to WSU. The similar course

pattern is followed at WSU having in-depth coverage in more than two technical areas (Table II).

TABLE II. SUBJECT CONTENTS OF CIVIL ENGINEERING PROGRAM AT KUET AND WSU

KUET	WSU
Semester 1	
Surveying	Mathematics for Engineers 1
Chemistry 1, T, L	Engineering Computing
Mathematics-I	Engineering Physics
Physics 1, T, L	Introduction to Engineering
English T, L	Practice
Sessional on Basic Electrical Engineering	
Civil Engg. Drawing 1	
Semester 2	
Engineering Mechanics	Mathematics for Engineers 2
Chemistry 2, T, L	Electrical Fundamentals
Mathematics 2	Fundamentals of Mechanics
Physics 2, T, L	Engineering Materials
Economics & Accounting	
Civil Engg. Drawing 2	
Semester 3	
Mechanics of Solids 1	Surveying for Engineers
Engineering Materials T, L	Mechanics of Materials
Mathematics 3	Fluid Mechanics
Fluid Mechanics T, L	Soil Mechanics
Sociology & Government	
Details of Construction Lab	
Semester 4	
Mechanics of Solids 2, T, L	Pavement Materials and
Numerical Analysis and Computer	Design
Programming T, L	Introduction to Structural
Engineering Geology & Geomorphology	Engineering
Hydrology	Environmental Engineering
Mathematics 4	Hydraulics
Estimating Lab	
Practical Surveying	
Semester 5	
Structural Analysis and Design 1, T, L	Structural Analysis
Reinforced Concrete Structures 1	Surface Water Hydrology
Geotechnical Engg. 1, T, L	Concrete Structures
Environmental Engg.1, T, L)	One alternate unit
Engineering Hydraulics T, L	
Semester 6	
Structural Analysis and Design 2	Steel Structures
Reinforced Concrete Structures 2, T, L	Engineering Geomechanics
Geotechnical Engg. 2 , T, L	Numerical Methods in
Environmental Engg 2, T, L	Engineering
Transportation Engg.1, T, L	One alternate unit
	Industrial Experience (Eng)
Semester 7	
Project & Thesis	Engineering Project 1
Project Planning & Construction	Engineering Thesis 1:
Management	Preliminary Investigations
Structural Analysis and Design 3, T, L	One alternate unit
Geotechnical Engg. 3	One elective unit (level 2 or
Transportation Engg 2, T, L	higher)
Irrigation and Flood Control	
Semester 8	
Project & Thesis	Transportation Engineering
Optional units (Structural Engineering):	Engineering Project 2
Sessional on Structural Analysis & Design 3	Engineering Thesis 2:
Prestressed Concrete	Detailed Investigations
Theory of Elasticity and Elastic Instability of	One alternate unit
Structures	*Alternate units:*
Introduction to Finite Element Method	Applied Mechanics
Structural Dynamics	Composite Structures
Design of Steel Structures	Highway Infrastructure
Optional units (Geotechnical Engineering):	Hydrogeology
Sessional on Geotechnical Engineering 3	Pile Foundations
Geotechnical Engineering 4,5,6	Statistical Hydrology
	Sustainability and Risk
Optional units (Environmental Engineering):	Engineering
Sessional on Environmental Engineering 3	Timber Structures
Environmental Pollution Control	Waste Management
Solid Waste Management	Water and Wastewater
Environmental Development Project	Treatment
Optional units (Transportation Engineering):	Water Resource Engineering
Sessional on Transportation Engineering 3	*Elective units:*
Transportation Engineering 3,4,5	Modern Construction
Optional units (Water Resources	Enterprises
Engineering):	Modern Construction
Sessional on Water Resources Engineering	Projects
River Engineering	Special Technical Project
Coastal Engineering	
Hydraulic Structures	
Ground Water Engineering	
Optional units (Others):	
Professional Practices & Communication	
Skills	
Socio-economic Aspects of Development	
Projects	
Integrated Water Resources Planning and	
Management	

T: Theory; L: Laboratory

The core technical areas of civil engineering were taught from 5th to 8th semester having analysis and problem solving, experimentation, data interpretation in both KUET and WSU (Table II). However, the principles of sustainability in design, public policy, and professional ethics are addressed poorly at KUET compared with WSU. One year research project having complex civil engineering context is included in the curriculum at KUET and WSU. Industrial experiences for students need to be incorporated in the KUET curriculum similar as WSU.

TABLE III. CATEGORY WISE CURRENT SYLLABUS OF CIVIL ENGINEERING PROGRAMS AT KUET AND WSU

KUET	WSU
Humanities	
Economics and Accounting	Introduction to Engineering
English	Practice
Sociology and Government	Two free electives from any other WSU degree programs
Mathematics	
Mathematics 1,2,3,4	Mathematics for Engineers 1, 2
Basic and Applied Science	
Physics 1,2	Engineering Computing
Chemistry	Engineering Physics
Surveying	Surveying for Engineers
Engineering Materials	Engineering Materials
Numerical Analysis and Computer	Numerical methods in
Programming	Engineering
Introduction to Finite Element Method	
Allied Engineering	
Sessional on Basic Electrical Engineering	Electrical Fundamentals
Structural Engineering	
Engineering Mechanics	Fundamentals of Mechanics
Mechanics of Solids 1,2	Applied Mechanics
Structural Analysis and Design 1,2,3	Mechanics of Materials
Reinforced Concrete Structures 1,2	Introduction to Structural
Prestressed Concrete	Engineering
Theory of Elasticity and Elastic	Structural Analysis

Instability of Structures	Concrete Structures
Structural Dynamics	Steel structures
Design of Steel Structures	Composite Structures
	Timber Structures
Geotechnical Engineering	
Engineering Geology & Geomorphology	Soil Mechanics
Geotechnical Engg. 1,2,3,4,5,6	Engineering Geomechanics
	Pile Foundations
Transportation Engineering	
Transportation Engg. 1,2,3,4,5	Pavement Materials and Design
	Transportation Engineering
	Highway Infrastructure
Environmental Engineering	
Environmental Engg 1,2	Environmental Engineering
Environmental Pollution Control	Waste Management
Solid Waste Management	Water and Wastewater
Environmental Development Project	Treatment
	Sustainability and Risk
	Engineering
Water Resources Engineering	
Fluid Mechanics	Fluid Mechanics
Hydrology	Hydraulics
Engineering Hydraulics	Surface Water Hydrology
River Engineering	Hydrogeology
Coastal Engineering	Statistical Hydrology
Hydraulic Structures	Water Resource Engineering

IV. Program Outcome and Improvement Option

The curriculum of KUET and WSU is analysed based on program outcome stated in BAETE accreditation criteria. The attainment of program outcome is mentioned in Table IV. The curriculum of civil engineering at KUET is highly addressed for achieving the program outcome of engineering knowledge, problem analysis, design of solutions, and investigation. Significant weakness is observed in the KUET curriculum in the criteria of sustainability, modern tool usage, ethics and project management areas.

TABLE IV. Attainment of Program Outcome

Program Outcome	KUET	WSU
Engineering Knowledge	H	H
Problem Analysis	H	H
Design/Development of Solutions	H	H
Investigation	H	H
Modern Tool Usage	P	H
The Engineer and Society	M	H
Environment and Sustainability	P	M
Ethics	P	M
Individual and Teamwork	M	H
Communication	M	H
Project Management and Finance	P	M
Lifelong Learning	M	H

Adequacy level: H – Highly; M – Moderately; P –Poorly

The curriculum of WSU is adequate related to interaction with industry in terms of industrial collaborated research, internship and their input for curriculum improvement (Table V). However, industry relation was addressed poorly in the KUET curriculum which is required to improve for the betterment of civil engineering graduates. The existing curriculum of KUET can be improved by incorporating community based learning process, moral and observable assessment process, sustainability education in civil engineering design [5], blended learning approach [6], and/or Conceive-Design-Implement-Operate (CDIO) principles [7]. The improved and adequate civil engineering curriculum can produce graduate civil engineers having adequate knowledge, technically skilled, moral attributes.

In WSU civil engineering course, publication of refereed papers by final year students are highly encouraged, and many good journal and conference articles have been written by the final year students. The academics in civil engineering at WSU are active researchers and have published over 700 ISI listed journal articles and received multi-million dollars in research funding and have numerous national and international collaborations and have over 50 current PhD students. KUET should target to enhance its research and industry collaborations to elevate its world ranking in civil engineering discipline by introducing research-industry-focused degrees.

TABLE V. Interaction with Industry

	KUET	WSU
Industrial advisory panel	N	Y
Participation of industry in academic updates	Y	Y
Internship	N	Y
Final year thesis project having industrial collaboration	N	Y
Industry visit	Y	Y

V. Conclusion

The curriculum of Khulna University of Engineering & Technology (KUET), Bangladesh and Western Sydney University (WSU), Australia is evaluated. It is observed that the curriculum of KUET is adequately addressed the civil engineering knowledge, problem analysis, design and investigation, however, does not provide adequate focus on sustainability, ethics, and state-of-art facilities. An improved curriculum can be introduced in KUET, Bangladesh similar to WSU, Australia to meet the graduate skillset required nationwide and worldwide. Since WSU and KUET has signed a MoU, they can work together to enhance the civil engineering courses in both the institutions.

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A Young Engineers Perspective On The Construction Industry

Yiana Pallis
Sydney, Australia
ypallis@hotmail.com

Abstract—My name is Yiana Pallis, I'll be 30 years old in December, I am from Western Sydney and I am a Civil Engineer. I started my degree at what used to be called UWS now WSU what seems many years ago. I was the lucky one. Lucky enough to know the right people to get an introduction into a good engineering company for my work experience and lucky enough to have a good engineering project supervisor for my final year engineering project. Lucky enough to work on some of the biggest projects in NSW and now lucky enough to serve my Country. The following paper will discuss the many lessons I have learned along the way not just as a female working in the construction industry but as an engineer in general.

Keywords— Gender; Diversity; Lessons

I. INTRODUCTION

I graduated from UWS in 2013 and along with my classmates found it extremely hard almost impossible to find a job in the industry. I was the lucky one though. Lucky enough to have the email of HR for a company working in Newcastle and lucky enough to gain employment there for my work experience and, lucky enough to still be in the system when they eventually needed engineers again. My work experience was in 2012 and I remember being a little nervous to start. After all my experience was word of mouth from a few lecturers about what the industry was like. I was keen on becoming a designer after finishing my degree and it was the only thing I was absolutely set on. Give me programming, formulas and modelling any day. So I started my first day of work experience a little sceptical, I was given all my PPE and shown around the worksite, given a tour of the construction world and I never looked back.

The project was the $1.7bn construction of a new four lane freeway link between the Pacific Motorway near Seahampton and the New England Highway west of Branxton. I worked on the F3 Interchange section on the project. This was my first experience in the construction industry and I loved it. The reason I had decided to become an engineer was that I wanted to build and the construction industry fulfilled that need. The project also gave me one of my first valuable lessons, respect is a currency and just like currency it needs to be earned.

II. FIRST LESSONS ARE THE IMPORTANT LESSONS

I was lucky enough to work under two engineers during my time on the project (an analogy of course!), both on complete opposite ends of the spectrum. One was the classic textbook 'this is what my textbook says, you are doing it wrong' and the other was the shrug and 'we will sort it out' type of engineer. I learned quickly that there was a fine balance between both. 'this is what my textbook says' never had respect from the foreman and the work was completed as late as possible with little urgency more out of spite to the textbook than to anything else and 'we will sort it out' lost respect from the foreman because they were allowed to run riot on site with no direction or leadership. My lesson from both was that, yes I am an engineer but that doesn't mean I should disregard the opinion or experience of my foreman who more often or not had 30+ years on me; but at the same time I had to learn to give clear direction on what I wanted to happen on site, after all there was a program and a budget I was supposed to be keeping to.

III. WORK YOURSELF OUT OF A JOB

Then comes the classic job shortage where there is always an approaching election and uncertainty on jobs. I spent a few months as a data technician before getting a call on an opportunity. A $675 million project providing a 27km highway upgrade, lots of soft soils so lots of soft soil monitoring, earthworks, bridges, a lovely green fields project, my favourite. Working with the same company meant working with the same people from my previous project, which I was grateful for. I learnt a lot from my colleagues. The biggest lesson from my fellow female site engineer, who was the epitome of work yourself out of a job. A lesson I carry into all jobs I've had since.

I was also lucky enough to re connect with another female engineer from my previous project, who became a mentor to me not just at work but through life, we still remain the best of friends today. If I am honest that project was excellent. The exposure I had to strong female engineers was second to none, the biggest lesson I learnt from that experience was about how to stand up for yourself and to know your worth. Good advice for all.

That being said however I experienced the first of only ever two times throughout my career where something was said to me that was way past my threshold of what was very inappropriate against my gender. Lucky for all involved they realised how over the line the comment was and a swift apology was delivered. There were other instances, someone asking me if I knew what was happening with a colleague's health issues because they were stomach related and I was female so I would automatically understand what was going on with her, the constant question asked of female engineers when they would be getting married and having kids, a female engineer being chastised for asking a question about the change to the company's maternity leave, someone walking up to us and boasting about how there is no more glass ceiling anymore! Just some of the few we experienced during our time on the project.

IV. KNOW YOUR WORTH

After my job was done I moved back to Sydney to start on a new project. The $4.3bn job involved roughly 9km of new tunnels, a new interchange and a local road upgrade. I was involved in the local road upgrade. I was for the most part the only female engineer in the local roads section. I was the token female engineer, I did get roped into courses and meetings for

women in engineering related programs. I quickly realised I neglected to follow the advice I had learnt and readily gave; know your worth. I didn't stand up for myself when I should have and ended up in a graduate program, a step down in pay and job title. All the while a recently hired site engineer with no experience straight from university was in the job I was supposed to be in. I realised then, know your worth! I knew I was a crucial part of the project and I knew I was being head hunted. I let my boss know that afternoon when I had realised my grave mistake. But guess what happened? I had the job title and pay by the end of the week, It pays to know your worth!

I mentioned that I was the token female engineer for this project, in reality I wasn't. I was lucky enough to be afforded the same opportunities and the same pay as my colleagues which I was grateful for. I maybe had to force a promotion but I was treated with absolute respect and that came through hard work.

I however remember a story of when I was going to get an undergraduate to work with me, and my colleagues mentioned she was female, I was puzzled when they mentioned that, what did it matter? My undergraduate was going to be doing all my paperwork anyway, irrespective of gender. But one comment threw me, "ooh you're going to have some competition", in what? Our jobs are defined, in what way was there going to be competition between us.

I thought it was strange, as if we were being pitted against each other before we had even met. According to Engineers Australia the statistics tell us that women make up only 11.8 per cent of the engineering workforce in Australia [1]. In that local roads team I was the only female engineer out of a total of 34 engineers, I'll leave you to do the math.

V. IMPORTANT LESSONS TO WORK AND LIVE BY

I learnt many valuable and very important lessons on that project. The first being about leadership. Don't be the person who calls up your leading hand and tells them what to do and assume it will be done, all the while sitting in your lovely air conditioned office. Be the person that calls your leading hand and shows them what to do on the worksite, a quick walkthrough outside the office on a hot or cold and rainy day earns a bit of respect. Working nights and its pouring rain? Stand outside with them and watch them work, help them out, raid the store later on in the night and find them some dry PPE.

The second lesson, write everything in your diary. Important meetings and phone calls and dates and people and discussions and weather. I can't stress this enough, as a young engineer people will try and throw you under the bus, even a colleague. Write everything in your diary! The third lesson I learned the hard way and came hand in hand with the second lesson. Read everything you sign and don't make assumptions. I almost caused a massive incident because I was complacent one morning and made an assumption. The fourth, own up to your mistakes and show integrity, there's nothing worse than working with someone who refuses to do this and shifts blame. After all a good leader directs praise away from themselves and onto their people and absorbs the blame and criticism for mistakes and failure. Don't mix these up, you will come across people that do.

VI. REPUTATION AND RESPECT

I grew up on my grandparent's farm in Western Sydney, so I was used to getting dirty and didn't shy away from hard work. So I guess the attitude I had, helped with my relationships with my foreman and leading hands on site. When I started I did notice a bit of a shift in how people acted and spoke to me. Throughout my career I was usually the only female in my sections of work. I do remember it took around a week before anyone even swore in front of me! But after that week I noticed no difference in how I was treated. I've noticed however there are a few that use this to their advantage, bat their eyes to receptive people and get what they want. The construction industry is a small industry and word travels fast. I remember moving to my last project and before even starting I had a phone call from another colleague alerting me to watch out for someone on the job.

I still have come across people who have treated me differently because of my gender, I call them 'the old guard'. They are far and few now but interesting when met. I have had someone ask to speak to the engineer not believing I was the engineer, had people not listen or respect me because I was female, had people tell me I was the token female engineer hire for gender diversity and that I didn't deserve my job, I've heard it all. The difference in these situations was that I had earnt the respect of the people working for me and with me, so when challenged by the 'old guard' I had plenty of the new supporting me. I was lucky

VII. LAST ADVICE

When I told my mum I was joining the Australian Defence Force she was not impressed. So many bad stories she said, I gently reminded her bad stories sell more papers and that I worked in construction.

The lovely lady in my interview told me to prepare working long days, I smiled; I was used to working extremely long hours usually eating breakfast lunch and dinner at the office. She told me to prepare for the differences in gender diversity for specific roles, I smiled; remembering the 5 of us girls in the class of 300 at university. Maybe it was also remembering the times I had worked alone as a female engineer, which never bothered me, why should it? The gender mix on my last project was a total of 59 per cent Male to 41 Per cent female [2]. That number however includes everyone on the project and isn't indicative of just women in non-traditional roles.

I have more female colleagues now in the Australian Defence Force than I had during my time in construction! A quick look at the Women in the ADF Report 2016-17 shows an increase in female participation rates to 17.9 per cent [3], so I am not wrong in my statement.

My advice is to not be that person that bats the eyes. Be the person that works themselves out of a job, let your competency and experience do the talking. Respect is earned, earn the respect from the people who work for you, shift praise and take the blame. Always and always write in your diary and most importantly stand up for yourself and know your worth.

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Rainwater harvesting for drinking purposes in rural areas: A case study in Western Sydney

Dina Ali Agha
Western Sydney University, Sydney, Australia
dina156ali@hotmail.com

Ataur Rahman
Western Sydney University, Sydney, Australia
a.rahman@westernsydney.edu.au

Mohammad A Alim
Western Sydney University, Sydney, Australia
m.alim@westernsydney.edu.au

Reyad Roy
Western Sydney University, Sydney, Australia
reyad.roy@westernsydney.edu.au

Muhammad M Khan
Halal Australia, Level 6 & 7, 91 Phillip Street, Parramatta 2150, Australia

Shafiq Shirin
Halal Australia, Level 6 & 7, 91 Phillip Street, Parramatta 2150, Australia

***Abstract*—The objective of this paper is to develop a simple low-cost slow sand filter system that would remove contaminants commonly found in roof harvested rainwater. Experimental results of four different slow sand filters are analysed to evaluate the water quality before and after filtration and to compare with the Australian Drinking Water Guidelines (ADWG). The water is tested for specific properties such as taste, colour, odour, microorganisms and chemical contents. There are two specific research questions that this research has answered. Firstly, can a simple slow sand filtration system be developed to filter harvested rainwater for drinking purposes in rural areas? Secondly, does the filtered rainwater quality meet the ADWGs? It has been found that the slow sand filter is capable of treating the roof harvested rainwater adequately; however, the study needs to be continued over at least one year to test for general weather and hydrological conditions.**

Keywords—Rainwater harvesting, water quality, slow sand filtration, drinking water

I. Introduction

Water covers most of the planet and it is life's most basic need. Due to growth in population, pollution and drought, the demand of water has grown significantly over time. Majority of developing countries still do not have access to clean drinking water [1]. Australia is listed under one of the driest countries on earth [2]. With the increase of population, it is believed that Australia will not be able to escape the pressures of finite supply of water. A segment of Australian history has shown different episodes of droughts; a major one is referred to as the Millennium Drought, which happened during 1996 - 2009. This is stated as the worst drought in 110 years [3]. Currently, Australia has been facing one of worst droughts in history.

Approximately 11% of the world's populations (790 million people) do not have access to clean water. Majority of these people live in rural areas and do not have access to a main water line. This is due to the fact that building a main water supply system for a small rural community is not financially viable.

Industrial development, recreational activities and residential infrastructure destroy the quality of water and make it inconsumable decreasing access to clean water even more [1]. At the current water consumption rate, this situation will only get worse. It is believed that by 2025, two-thirds of the world's population may face water shortages and ecosystems around the world will suffer even more. This has led to the use of RWH systems as an alternative water source in smaller cities and rural areas. Water tanks have grown popular due to increased environmental awareness and scarcity of water restrictions in many cities. RWH is increasingly being implemented globally to help solve water demand issues, but mainly to save mains water [4].

Rainwater is one of the purest forms of water. RWH is a system where surface runoff is effectively collected during rain periods [5]. The application of RWH is increasingly being used as it is highly efficient resource for non-potable uses and irrigation [6]. In Australia, the installation of RWH system has been encouraging for non-potable purposes.

Very little research has been implemented on the use of harvested rainwater as a source for drinking purposes [7]. Many rural areas in Australia do not have access to water supply through a main line; they access water by harvesting rainwater. The collection of the rainwater is basically through the rooftop to the gutters to the harvesting tank. They use harvested rainwater for irrigation, domestic use and drinking water. However, this rainwater may not meet the drinking water guideline.

Main factors contribute to the contamination of rainwater include roofing and tank materials, animal and bird droppings, dust, paints, leaves, and atmospheric contaminants. Many people have a miss perception that harvested rainwater is appropriate to drink without treatment. However, treatment is

required when rainwater is used for drinking purpose as recently found in an Australian study [8].

Harvested rainwater passes through two tanks; the first smaller tank, also called the first flush, where all the larger solids settle allowing the rainwater to flow to the next tank with less pollution, i.e. the settlement of the initial pollutants of the harvested rainwater. The second tank is the storage tank of the harvested rainwater. Although the rainwater passes through the first flush and flushes away the pollution, the rainwater is not completely clean or healthy to consume. Due to this, treatment is required, and filtration is needed indeed.

Trace elements found in harvested rainwater may have negative effect on the risk of health of human if the water is consumed without treatment. The most hazardous trace elements are heavy metals. Heavy metals exposure to human bodies can create health problems like kidney diseases, lung fibrosis and irregularities in the blood composition. Mental and central nervous function or even death can be possible when heavy metals are accumulated in the human body over a long period of time.

Previous research has proven that heavy metals such as cobalt (Co), iron (Fe), magnesium (Mg) and molybdenum (Mo) are essential nutrients for many biochemical and physical functions. Trace elements such as Fe, iodine (I), fluoride (F2-2), copper (Cu), zinc (Zn), chromium (Cr), selenium (Se) and manganese (Mn) are vital for maintaining health, however only small quantity is required [9]. De Oliveira Moura et al. [10] conducted an experiment, testing 36 tanks (which were installed in two rural communities of the semiarid of Bahia, Brazil) for any trace elements. Trace elements such as Cu, Zn, Ba, Al and Fe, were frequently found, and Fe was above the tolerable limit for drinking water [11].

Simple filtration is needed to purify the harvested rainwater. Slow sand filter, also called “Biological Filtration”, is one of the simplest treatments and that is known to be economical and reliable is a simple slow sand filtration system. It is known that at a rate of 0.1- 0.4 m/h water slowly passes through a bed of fine sand which removes pollution such as turbidity and it reduces the harmful pathogens found in rainwater [11]. The slow sand filter can remove bacteria such as Escherichia coli (E coli) between 2.25 and 3.92 logarithmic units [12] and improve the quality of water for public supply [13].

This project assesses the use of rainwater for drinking purposes, intended for rural applications. The aim of the research is to create a slow sand filter which will be efficient enough to purify harvested rainwater from the tank. The experimental results are compared to the Australian drinking water guidelines.

II. MATERIALS AND METHODS

The study considers rural areas in Penrith, NSW, Australia. The rainfall data of Penrith area is considered from year 1971 – 2018. A distribution of the monthly rainfall of Penrith area is shown in Figure 1. The roof area is considered to be 484 m^2 with four occupants.

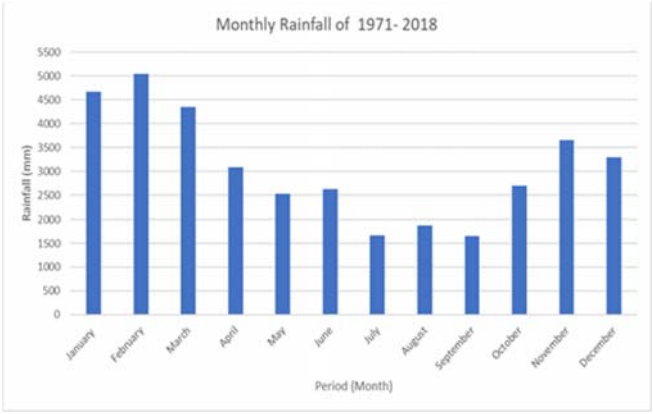

Figure 1 - Monthly Rainfall Data of Penrith from 1971 - 2018

The study develops a water balance model to analyse water availability based on daily rainfall data falling on a roof catchment. Water uses from tank include toilet and laundry use, irrigation use, drinking water and combined use of all of these. The water balance model is based on a typical property in Penrith rural area. The water balance model also includes water losses in the first flush, which is considered to be 100L per rainfall event.

In the excel based water balance model, which is based on a daily time scale, different factors are considered such as roof size, tank size, daily rainfall data and spillage. Throughout this model inflow and outflow are regarded as rainfall and spillage, respectively using the method of [14]. The following equation is used to estimate the release of water from the tank:

$$R_t = D_t \quad \text{if} \quad I_t + S_{t-1} \geq D_t \tag{1}$$

$$R_t = I_t + S_{t-1} \quad \text{if It} + S_{t-1} < D_t \tag{2}$$

D_t = daily demand (m^3) on day t

S_{t-1}= tank storage of the end of the previous day (m^3)

R_t = release from rainwater tank (m^3)

I_t = inflow (m^3)

For spillage calculations, the following equations are used:

$$SP_t = I_t + S_{t-1}D_t - S_{MAX} \quad \text{if} \quad I_t + S_{t-1} - D_t > S_{MAX} \tag{3}$$

$$SP_t = 0 \ \text{if} \ I_t + S_{t-1} - D_t \leq S_{MAX} \tag{4}$$

SP_t = Spill (m^3)

S_{MAX}= design storage capacity (m^3)

S_t at the end of day t can be calculated using the following equations:

$$S_t = S_{MAX} \quad \text{if} \quad SP_t > 0 \tag{5}$$

$$S_t = S_{t-1} + I_t - R_t \quad \text{if} \quad SP_t \leq 0 \tag{6}$$

The reliability of a rainwater tank is calculated as the ratio of the number of days that met the water demand over the number of days analysed.

A sand filter is built using five materials, which are presented in Table 1 with their purposes in the filter. The materials are placed in a 1 m long food grade PVC pipe with 90 mm diameter. Water samples are collected in sampling bottles and carried to Environmental Engineering Lab at Kingswood (Building Y), WSU and tested for selected water quality parameters.

Table 1 Slow Sand Filter Materials and their Purposes.

MATERIAL	MATERIAL PURPOSE
SAND	Fine sand's structure consists of small sand particles that are tightly packed.
GRAVEL	Gravel's Structure consists of small and large particles that are loosely packed.
LIME STONE	Help adjust the pH of the water.
CHARCOAL	Removes unwanted chemicals and impurities from the water leaving the healthy minerals and ions. It also removes the flavour.
CHEESECLOTH	Holds the sand and charcoal, preventing them from mixing with the filtered water.

III. RESULTS AND DISCUSSION

The water balance analysis reveals that none of the water combinations in particular drinking water, for all tank sizes have a 100% reliability of meeting the daily drinking water demand. Another factor that is considered is water spillage from the rainwater tank, which is essentially the overflow of excess rainfall flowing into the tank when the rainfall is too heavy. To overcome a spillage issue, a backup tank can be installed, or a larger tank size can be used. From the analysis, it is seen that with the increase of tank size; the amount of days meeting the daily drinking water demand increases, the reliability increases, the total water saved increases and the total spillage decreases.

For this study, the most effective rainwater tank that covers drinking water demand on a daily basis is 20kL tank size as it shows the reliability of approximately 96%.

As a treatment system, a slow sand filter is proposed. Different filters are constructed to find the most effective slow sand filter that would clean the harvested rainwater to allow for consumption. Experiments were conducted to find the effective layering of materials and effective sand depths in the filters. The materials used were fine sand, gravel, limestone, charcoal and cheesecloth. Experiment 1 consisted of 2 filters (F1 and F2) with same depths of materials (sand being 0.5m) but different positions in the filter. The most effective filter in terms of carrying the water is selected for experiment 2 to test different depths of sand. The most effective positioning from the bottom is sand, charcoal, cheesecloth, limestone and gravel.

Experiment 2 consists of two filters (F3 and F4) that had sand depths of 0.4m and 0.3m. The rainwater that was used came from 3kL rainwater tank at Werrington South Campus of Western Sydney University (WSU), which is part of the funded research project led by Prof Ataur Rahman (WSU) to produce drinking water from harvested rainwater. Two sets of samples are taken over a two-week interval to find the effectiveness of the filters over a period of time. During this two-week period, heavy rainfall has occurred, and new rainwater is harvested. During the collection of samples, an observation is made in regard to charcoal. It is seen that charcoal particles are able to pass through the cheesecloth and be present within the water samples. This suggests that although the positioning is more effective in terms of carrying the water, it is not effective in terms of keeping all filter materials together. It is recommended that charcoal should be positioned above the sand as no charcoal is seen in the water samples for F2 (experiment 1). Another recommendation is to allow more flushing time to flush out all small charcoal particles.

Laboratory experimentations are conducted on the collected water samples. Generally, when testing water for drinking purposes in Australia, all parameters in the ADWG need to be tested. However, due to time restrictions, common parameters are selected taking in consideration of the location of where the rainwater is harvested.

The parameters that are tested here include pH, turbidity, DO, EC, TOC, TC, IC, NO_2, NO_3, Pb, Cu, Zn and E. coli. Raw water (tank water before filtration) was tested to find the original value of each parameter and compare with the filtered water. Through the results most of the raw water values comply with the ADWG. For some parameters the filtered water decreases the values suggesting that the filters are effective (such as NO_3, Pb and Zn) and the filtered water increases the values like the TOC, TC and IC. This suggests that there is a material within the filter that contains high organic matter e.g. charcoal or cheesecloth as it is made out of cotton. To improve the TOC, TC and IC values, it is recommended not to include the cheesecloth as a layer in the filter.

In terms of the E. coli, all values are less than 1, which does comply with the ADWG. These values are provided by a NATA accredited private lab. Also, when Set 1 samples are collected they are left at room temperature for 2 weeks before sent to the private company for testing. There may be a possibility that the result is not completely accurate.

From the results, it is difficult to see the most effective filter out of the four, as some filters are effective in some parameters and some are not in other parameters. It is recommended that more samples should be taken at different time frames and tested to see the pattern. The test should be continued for over a complete year.

IV. CONCLUSION

This study assesses the use of harvested rainwater for drinking purposes in rural areas of Penrith, NSW, Australia for a typical rural household with four people. A water balance model is developed considering the daily rainfall data of 1971-2018, to distinguish which rainwater tank size (5kL, 10kL, and 20kL) would meet the daily drinking water demand. Also, four different filters are constructed to determine the optimum positions of the slow sand filter materials and suitable sand depths.

The most effective tank size is found to be the 20kL tank as it gives approximately 96% reliability in meeting the daily

drinking water demand in rural areas in a typical household. The slow sand filter that is constructed for this study is not completely effective in treating harvested rainwater adequately for drinking purposes. This is due to the filtered water not meeting the ADWG for some of the parameters that is tested. There are a number of issues that have been identified which might lead to the poor quality of filtered water:

- There is an increase in TOC, TC, and IC in the filtered water.
- Storing at room temperature might affect the water quality.
- Three filters are releasing charcoal particles when samples are collected.

All materials needed for the slow sand filter are low on cost and the slow sand filter can be easily made at home. However, it is recommended that more research should be conducted for making a recommendation.

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Sydney Metro Northwest Viaduct Type 1 Track Slab

Thy Pham
Parramatta Connect
CPB Contractors
Sydney, Australia
Thy.Pham@pcplr.com.au

***Abstract*— In March 2017 I was engaged as a Junior Engineer on the first stage of the $2.81b Sydney Metro works, the Sydney Metro Northwest project. I was responsible for multiple key deliverables for the viaduct rail install and ballasted track portion of works. The works were delivered to a high standard that involved the effective management of multiple challenges associated with viaduct handover from the client, resulting in innovations using top-down equipment to support and enhance the construction methodology.**

The technical paper illustrates the technical stages and building activities for the viaduct and Type 1 Track Slab portion of works for Australia's first Metro network. The paper covers the entirety of the viaduct's lifecycle, including its corresponding subsystems, and innovative mitigations to address project challenges including the late handover of the asset from the Surface and Viaduct Civil Works (SVC) contractor in early-mid 2017. Other components include incorporating major design changes, defects management, construction and delivery of the track, and finalisation of commissioning and testing in readiness for handover to the Services Joint Venture (SJV).

The size and technical complexity of the project provided multiple challenges to delivery, compounded by demanding timeframes and delays in handover of the viaduct from the client. The key difficulties overcome on this project included:

- **The late handover of the viaduct from the client required changes to design to meet milestones and maintain quality.**
- **Use of a new grout mix Megapoxy.**
- **Installing track on a constantly moving bridge with settlement**
- **Weather – heat resulted in rail creep and bridge expansion**
- **MOD66: A highly challenging ballasted track install requiring track possession.**

The construction methodology for the Infrastructure JV scope of works was characterised by innovative approaches including modifying temporary works equipment (top-down equipment), and an Type 1 Track Slab methodology used to install the rail. Other innovations include trials of new grout mixes, and those associated with the welding expansion switch.

The successful delivery of the viaduct track slab was performed against demanding time-frames, within a highly congested project footprint, and required works to meet complex specifications and high standards, as a minimum. These elements were achieved despite a number of challenges, including late handover of the viaduct, never before tested working methodologies, and the added pressure of delivering an iconic infrastructure project in a capital city. Meeting a minimum standard of technical excellence was inherent to a successful delivery, and is best demonstrated by the on-time, on budget handover of the viaduct to the TfNSW/SJV.

Keywords—Sydney Metro Northwest, Sydney Metro, Rail, Infrastructure

I. PROJECT DESCRIPTION

Sydney Metro Northwest is the first stage of the new metro rail line connecting Sydney's North West growth centre to the existing Sydney Trains network. It is the first component of the Sydney Metro line that will extend through a new harbour tunnel into the CBD to the South West. The line is a combination of repurposed existing rail line, new underground and overground rail lines.

CPB Contractors and John Holland formed the Infrastructure Joint Venture (Infrastructure JV), selected by TfNSW to design and construct the Sydney Metro Northwest Operations, Trains and Systems Package, with works commencing in March 2015. The Infrastructure JV scope of works included the following:

- 9.3km Type 1 Track Slab
- 27.23km Type 2 Track Slab
- 3.25km Type 3 Floating Slab Track (FST)
- 10.5km of Ballasted track
- Construction of the Sydney Metro Trains Facility
- Install of 5km 33kv cable route
- Convert of the existing Epping to Chatswood line and 5 stations to metro stations

- 43 turnouts and 3 diamonds
- Eight new stations at Tallawong, Rouse Hill, Kellyville, Bella Vista, Norwest, Showground, Castle Hill and Cherrybrook.

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A. Scope of Works

This report focuses on the scope of works of the Viaduct Type 1 Track Slab Delivery Team (the Track Team). The Track Team was made up of six junior and project engineers, responsible for the following scope:

- 9.3km of Type 1 Track Slab on the viaduct
- 4 x 1:18.5 R800 Turnouts
- 1 X 1:8.25 R160 Turnout
- 3 X 1:6.6 R160 Turnouts
- 1 x 1:9 R190 Scissor Crossover
- 3km Plain Line Track
- 2 x Expansion Switches for 300mm on Delkor Eggs
- 1,045 flash butt welds and 376 aluminothermic welds
- Noise attenuation (including parapet noise tiles, four-foot noise panels and rail dampers).

The viaduct spans 4.6km from Rouse Hill to Kellyville and encompasses two bridges; the 400m Second Ponds Creek viaduct, with 10 (115-124) spans averaging at about 40m per span. There is also the Mainline (ML) viaduct, with spans from 1 to 107. The Windsor road Crossing Bridge is a cable stay bridge on a tight curve, containing spans 108 to 114.

B. Construction Methodology

The handover of the viaduct from the client to the Infrastructure JV was delayed by over 12 months due to quality concerns. The delay in handover produced major complications that impacted defect management, rectification works and resulted extensive design changes. Through technical excellence across construction methodology, and a dedication to innovative problem solving, the Track Team absorbed schedule impacts with a revised design that expediated the program and secured delivery within the original timeframe, ensuring the viaduct was ready for dynamic and real-time train testing in-line with the scheduled first passenger service in May 2019.

To achieve this, the Track Team worked to deliver major construction activities in line with TfNSW's original completion dates, as outlined below in Table 1.

TABLE I. VIADUCT TRANCHE DATES

No.	Applicable Eligible Works	Incentive Completion Date	Tranche Date Achieved
1	Derailment kerb concrete works complete on SVC Portion 1A (Second Ponds Creek Viaduct)	21 July 2017	21 July 2017
2	Track slab concrete works completed, and rail laid at SVC Portion 1A (Second Ponds Creek Viaduct)	31 August 2017	31 August 2017
3	500m derailment kerb concrete works complete on viaduct SVC Portion 1E, 1C and 1F (Span 1 to 46)	11 August 2017	11 August 2017
4	Derailment kerb concrete works complete on viaduct SVC Portions 1E, 1C, 1F (Span 1 to 46)	15 September 2017	15 September 2017
5	300m track slab concrete works complete on viaduct SVC Portion 1E, 1C and 1F (Span 1 to 46)	29 September 2017	29 September 2017
6	Track slab concrete works and rail laid at SVC Portion 1E, 1C and 1F (Span 1 to 46)	01 December 2017	24 November 2017

The Track Team used a number of innovations to meet tranche dates, and employed a positive, demanding work ethic that often-involved skeleton crews working at high productivity.

To meet the Second Ponds Creek Viaduct milestone, I worked within a reduced Track Team of four team members worked in a labour-intensive three-day turnaround to manually lay all rail jewelry and track components within an exceptionally tight timeframe, after receiving delivery of the track slab. This achievement represented the first major milestone for the track installation, putting the schedule in good stead for consecutive targets.

II. Derailment Kerbs

The derailment scope followed a strict program and cycle. They underwent significant rectification works to support design changes, requiring an altered depth of cover to suit existing pre-cast stirrups The SPC Viaduct derailment kerb width was expanded from 330mm to 440mm, the ML Viaduct and WRSSC Bridge derailment kerbs were expanded to 410mm.

A. Concrete Scabbling

To allow concrete bonding with the new, wider derailment kerb, concrete scabbling was required. As Junior Engineer, I was responsible for all concrete scabbling activities to ensure handover to the engineer responsible for the concrete scope.

FIGURE I Scabbled Concrete for Derailment Kerbs

FIGURE II FRP Works

B. Form Reinforced Pour Works for Derailment Kerbs

The subcontractor, alongside the track team, created an innovative gantry system that generated labour and time efficiencies. Form Reinforced Pour works for the derailment kerbs were completed at a production rate of 312 lineal meters per day.

III. Construction of the Track Slab

Construction of the track slab followed a strict program. Due to quality issues prior to handover, the viaduct was delivered to the Track Team with an irregular surface, and the original design of the track slab was no longer appropriate. To mitigate this, the original 1mm bituminous debonding layer was redesigned to 2mm.

FIGURE III FRP Works on the Track Slab

FIGURE IV FRP Works on the Track Slab

A. Form Reinforced Pour Works for Track Slab

Form Reinforced Pour works for the track slab were delivered at a production rate of 80 lineal meters per day.

IV. Track Installation

A. Top Down Equipment

The Track Team directly managed all works for the tracks installation, including developing and implementing the specialised Viaduct Type 1 methodology across equipment design.

This methodology involved building the track from the ground up, injecting the grout from the top down to fill in the voids. Innovative designs were required to ski the rail onto the viaduct for 4.1km, and to hold the rail to design horizontal (line) and vertical (height) alignment. The top-down equipment design was finalised and manufactured to design Viaduct Rollers, Iron Horses, Push Pulls and Grout Formers.

1) Mitigating a tight footprint

Working within a very tight footprint across the length of the viaduct and taking into consideration the loading capacity of the bridge, the use of heavy machinery to install rail components was not an option. To counter this, the Viaduct Type 1 construction methodology was implemented, and the design of project's viaduct rollers, iron horses and push pulls were modified and enhanced to allow for a seamless installation that employed manual install techniques.

B. *Viaduct Rollers*

The biggest challenge in designing the viaduct rollers was to ensure that 120m sections of rail could be 'skied' or slid onto the total length of the viaduct without the use of heavy machinery, that could not fit into the tight project footprint. To address this, the Track Team employed an innovative strategy that involved the redesign of rail temporary works and equipment.

The viaduct rollers were designed to fit into the existing track slab voids and able to screw onto a plate with the conical extrusion, ensuring the roller could still be used for future works with varying track designs. Viaduct rollers were spaced every 10.5m and were designed to be seamlessly slid into place across the total length of the viaduct. This design is illustrated in Figure V and Figure VI.

FIGURE V PLATE WITH CONICAL EXTRUSIONS

FIGURE VI VIADUCT ROLLERS

A 'ski' plate was attached to the rail and slid onto the viaduct via a Front End Loader (FEL). The purpose of the ski attachment, as shown in Figure VII , was to allow the rail to spool over the rollers effortlessly and smoothly, without staggering or damaging the rail or surrounding infrastructure. The ski attachment significantly increased the efficiency of the rollers, even when attaching multiple sections of 120m rail together.

This strategy generated significant time savings (by reducing the need to create new voids) and avoided further civil works that could have interfered with the integrity of the viaduct slab. The significant length of the Sydney Metro Northwest viaduct provided a unique opportunity to use this method, which would normally not be considered due to the labour-intensive nature.

FIGURE VII SKI ATTACHMENT ON RAIL

C. *Iron Horses*

An iron horse lifts the rail to vertical alignment, holding a standard track gauge of 1435mm and the 1:20 cant in the rail. The use of iron horses date back to the 1970s, and their cumbersome design (they weigh approximately 25kgs) has remained moderately unchanged. Although highly effective, iron horses pose a significant issue when working in congested work spaces. Prior to having track installed, the viaduct offered tight access, and using vehicle/machinery to relocate big bulky items was not an option. To mitigate this, new iron horses were initially considered with modifications to make them lighter and easier to transfer via man power.

FIGURE VIII TRADITIONAL IRON HORSES

An iron horse that came apart in two pieces was designed and manufactured. The new design was easily transportable via man power and eliminated the need for heavy machinery. The design went through a course of trials, tests and measurements on site with the manufacturer to ensure the highest accuracy of holding the track gauge and 1:20 cant of the rail. During this period, I learned how to use a gauge board and adopt various methods to take all critical measurements on plain line track.

The site team responded positively to new iron horses, and in turn allowed me to have full control on the precision and quality of the track geometry. As the iron horses were designed and manufactured in-house, any deformations or deteriorations could be sent back to the manufacturer immediately for rectification, without affecting production rates. Figure IX

showcases the specially modified/designed iron horses laid out on the viaduct.

FIGURE IX MODIFIED IRON HORSES USED ON THE VIADUCT

D. Push Pulls

Push pulls line the rail to design horizontal alignment and work alongside iron horses. The push pulls on the project went through two design changes. A curved attachment design was engineered to suit the web of rail and was tucked in between the head and foot, as detailed in Figure X. This design allowed swivel that enabled manipulation to the rail, where necessary. The other side had a bracket that braced the derailment kerb and held the whole assembly in place while the spindles allowed adjustment against the derailment kerb.

FIGURE X INITIAL PUSH PULL DESIGN

While these trials returned interesting and positive results, the push pulls eventually used on the project were the original design, after rail rolling was discovered during test and measurement checks.

The 1:20 cant critical measurement is 7.3mm, with a tolerance of +/- 0.4mm, however our measurements ranged between 5.0mm to 8.8mm. It was determined that the curved swivel on the iron horse caused unaccounted movement which rolled the rail out of the tolerance. As the curved swivel was designed to hold at the web, when the push pull was adjusted at the spindles, it encouraged movement on the top half of the rail, promoting a larger twist and cant. This concept is explained in Figure XI.

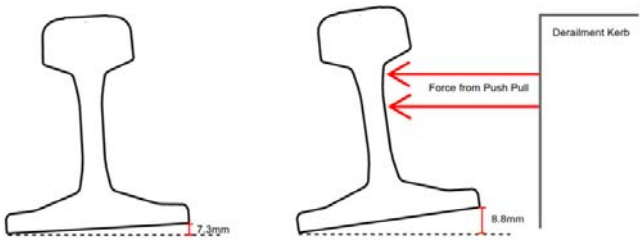

FIGURE XI EXAMPLE OF CANT IN RAIL – DESIGN VS. ORIGINAL PUSH PULL (NOT TO SCALE)

A traditional push pull concept was implemented to mitigate the movement at the head and web of rail, and restricted movement to the foot of the rail only. This design removed the bracket that braced from the top of the derailment kerb to a simple block that could be positioned perpendicular to the foot of the rail, as portrayed in Figure XII. This restricted the force from entering at an angle that promoted unwanted twist in the rail. The revised and final push pull design provided accurate track geometry measurements. Further modifications to the top-down equipment design and manufactured for the Viaduct Type 1 track slab, were made to allow 25m of Type 3 track slab on the underline crossing (ULX) at span 78 and another 25m for the expansion switch for the WRSSCB.

FIGURE XII FINAL PUSH PULL DESIGN

E. Grout Formers

It was vital that the grout former used suited the specifications of the grout, Megapoxy 206 Ultra. Specifications of the grout can be found in IV.FMegapoxy 206 Ultra.

To work in concert with the Viaduct Track Slab Type 1 methodology, the design of the grout formers had to form a pad underneath the baseplate, while allowing for a gap to allow installation of the grout.

Vivacity Engineering (Vivacity) was the specialist consultant and supplier engaged on the works. As the primary interface between Vivacity's Managing Director and the Track

Team, I conducted grout trials to determine the most appropriate mix and product. This included trials of PET plastic and PME Megapoxy. Figure XIV illustrates an unsuccessful and challenging trial pour that enabled me to identify requirements. I considered the following:

- Seals along the sides and bottom of the grout form, and
- Different material to withstand the heat given off the grout, concrete and rail during extreme weather conditions, to allow weight to hold down the seals.

FIGURE XIII VIVACITY GROUT FORMER

FIGURE XIV VIVACITY GROUT FORMER TRIALLED WITH MEGAPOXY PME

To achieve a high-quality grout pad, the design had to be at a respectable height to allow varying vertical alignments. The minimum grout pad depth is 10mm and the maximum depth is 40mm. Rubber seals were incorporated to secure the circumference of the base plate and the bottom to close any air gaps. This mitigates any air flow, which in turns reduces the voidage created underneath the baseplate itself and stops leakage seeping from underneath the grout former.

The initial steel grout form, as portrayed in Figure XV and Figure XVI, showcases the new design implementations in action. Designing and manufacturing this in steel is much more durable and can withstand extreme weather conditions, whereas the concept proposed by Vivacity Engineering could not. As steel is a heavier metal, it pushed its body weight onto the rubber seals to ensure they would be closed off. However, during the trial, the grout was still leaking through. I resolved this problem by introducing welding wedges underneath the rail to put additional weight down and secure the rubber seals, as I had witnessed the supplier using wooden planks in an earlier trial.

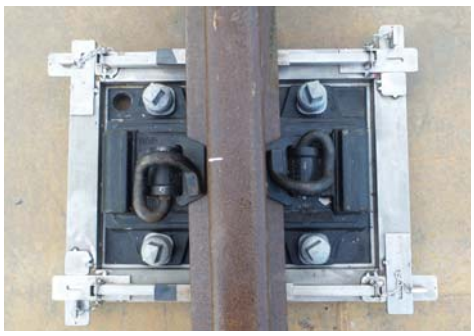

FIGURE XV INITIAL STEEL GROUT FORM DESIGN

FIGURE XVI INITIAL STEEL GROUT FORM DESIGN

Utilising the welding wedges underneath the rail to tighten and secure the grout form worked exceptionally well, without compromising track alignment. However, the cost purchase of welding wedges for the production rates I was aiming a considerable expense. I completed a value for money exercise to demonstrate to the Project Manager that it was cost effective to manufacture brace bars to sit underneath the rail, to ensure seals are secured. The brace bars were designed and manufactured specifically to suit the 1:20 cant of the rail, without compromising the quality of the track alignment. The final grout form design and brace bar assembly is illustrated in Figure XVII, it also shows a 20mm gap on the end of the base plate that enabled a seamless grout pour.

I also championed the use of welding mud to address all remaining gaps, further saving costs.

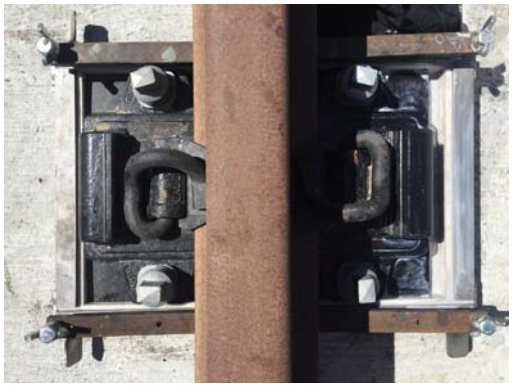

FIGURE XVII FINAL GROUT FORM DESIGN AND BRACE BAR ASSEMBLY

F. Megapoxy 206 Ultra

I worked with Vivacity to run trials on two types of grout Megapoxy PME and Megapoxy 206 Ultra. After designers approved Megapoxy PME, I organised trial pours alongside different types of grout formwork. Although Megapoxy PME is free-flowing and self-levelling, Figure XIV showcases its' workability was not suitable to our purposes.

Megapoxy 206 Ultra was proposed, but was challenging to get approved. At the time, there was no formal reference to dynamic and/or impact loading resistance and suitability for the under-baseplate application. After completing extensive research, I discovered Megapoxy 206 Ultra was used in an identical manner by Sydney Trains. I also completed compressive strength and modulus elasticity tests alongside Vivacity to ensure this product was suitable for the viaduct track installation, and able to withstand the designed dynamic loading of 60kN.

A mock trial of the viaduct on canted and tangent track was completed to ensure all components worked in harmony, and identify issues. An important component was to ensure the workability of the Megapoxy 206 Ultra was installed under the baseplate, without leaving excessive voids/air bubbles. The design required the voidage to be kept below a nominal 15% and in no cases exceed 30%. The trial was triumphally successful, with a rate below 5% of 10 out of 12 baseplates trialled. An example of this voidage rate is shown in Figure XVIII.

FIGURE XVIII MEGAPOXY VOIDAGE UNDERNEATH BASEPLATE

There were controversial challenges about the application of Megapoxy. In the past, the application was highly labour intensive, where it required a production line to mix the epoxy, distribute it and to apply it. The team adopted a "work smarter, not harder" approach, and trialled Vivacitys' existing design of a dispensing machine to reduce the intensity of labour work. Due to the complexity of the machine, the mixing ratios and distribution flow rate, there was a delay in getting the machine altered to make it more appropriate to the site footprint.

1) Trialling Vivacity Exposy Dispensing Machine

As a precaution, I designated 28 baseplates to be trialled during day shift, completing the 2 in 3 infills. Figure XIX shows it reduced the labour intensity as the site team is no longer on required a production line to encase the voids with jugs. Although the dispensing machine had an ideology of innovation, it was evident that the control and quality was compromised. Issues arise during the trial where the site team did not have control of the flow rate and struggling to maintain a neat and tidy track slab and baseplates.

FIGURE XIX VIVACITY EPOXY DISPENSING MACHINE

It was also noted that the consistency of the Megapoxy wasn't correct where the dispensing machine did not carry out the mixing ratio to specification. This was only noticed the following day when the Megapoxy did not set, but was still soft and gooey, as shown in Figure XX.

FIGURE XX UNSET MEGAPOXY

The manufacturer had advised the team to allow about half litre of Megapoxy go to waste so that the mixing ratio can kick in, however factoring in the cost of $11 per litre, 6.5 litre per

baseplate and a total of 26,486 Alt 1 RF192 Delkor baseplates, my team and I was not willing to spend the extra money to "go to waste". An executive decision was made between the track superintendent and myself to complete the viaduct the traditional way, where the quality cannot be compromised for shortcuts and that the team and I are proud of the quality of work executed.

G. Type 1 Track

Once all concrete works were completed, the track slab was handed over to Track Team. I managed two crews working over a 24-hour period to ensure milestones were met, without compromising quality.

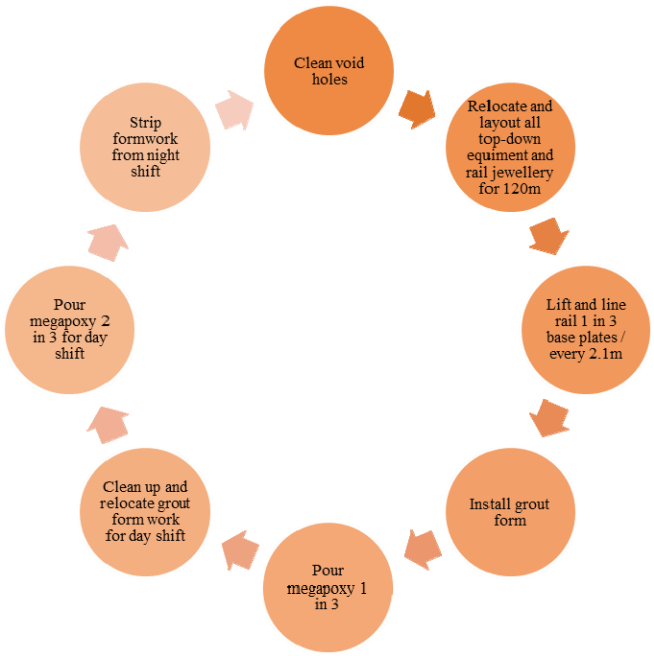

FIGURE XXI 24-HOUR VIADUCT TRACK INSTALL CYCLE

1) Night Shift

It was determined to lift, line and hold the track to the design horizontal and vertical alignment during the day was almost near impossible. As the viaduct is a concrete cable stay bridge, the concrete had to be kept at a neutral temperature to minimise movement when installing the track. To do this, construction activities were carried out at night in mid-September 2017, when the temperature was cooler.

The iron horses were spaced every 2.1m (every 3 baseplates) and allowed the night shift crew to lift and line the track to complete a 1 in 3 baseplate Megapoxy pour. This allowed the day shift crew to complete infills during the day, without compromising the horizontal and vertical alignment set at the night. As construction commenced in spring, the concrete neutral temperature was reached between 22:00 and midnight, and it was vital that the surveyors' completed the line and height of the track within that timeframe.

The curing time of Megapoxy became a top priority. It was important for the night shift's pour to set and harden by the morning (between 0600 to 0800) for the day shift to commence their scope. As the nights were much cooler between September to November, I engaged Vivacity to discuss fast-tracking options, and they provided an accelerant for the epoxy. This allowed the Megapoxy to set within 3 to 5 hours, as opposed to the nominal 6 to 9 hours of curing time and allowed me to keep up with the forecasted program.

I commenced night shift works with the site team and completed my quality walk-through and check sheet, prior to encasing the Megapoxy in the voids.

There were many environmental and community challenges that were faced during out of hours construction. I had to consider the scope of works, type of machinery, plant and hand tools that was permissible. Due to the restrictions of no hi-rail plant machinery, this was a challenge within itself as I had to prioritise the bulk relocation of tools, top-down equipment and materials during the day. Procurement of "silent" tools were also required to accommodate to construction at night.

2) Day Shift

It was important for the day shift track team to prepare the track slab in preparation for the night shift as they had time constraints to complete their scope. The team was required to complete the remaining scope of works to finalise the Megapoxy pour for the span, this included:

- Completing the 2 in 3 Megapoxy pour,
- Strip, clean and relocate the grout formwork,
- Vacuum/clean out the track slab void holes,
- Relocate top-down equipment and Megapoxy,
- Tighten screw spikes to 270-290kN, and
- Clean and buff the Megapoxy pads.

As the team and I worked through summer, challenges arose due to the heat. Issues with the epoxy setting too quickly and "bubbling" became a major concern. It was already known that Megapoxy cures and sets quicker in warmer temperatures, however this was further accelerated by the heat from the concrete bridge and track slab, rail and from the Megapoxy itself, which lets off 60-70°C. This caused a bubbling effect, as shown in Figure XXII.

FIGURE XXII "BUBBLING" MEGAPOXY

Towards the end of track construction on the viaduct, the influx of hi-rail plant and onsite staff increased, and interface management became a priority across the works. This was heightened by the single point of entry onto the viaduct and into the tunnel at Kellyville. I attended site meeting twice weekly to support communication and coordination of staff and prioritise activities. Effective management of these multiple interfaces was vital to ensure milestones were met.

In preparation for dynamic testing of the new metro trains, it was imperative that all works were completed to complex specification and high standards. There were known tolerances of the derailment kerb and the height of rail, but originally, there were no known tolerances of the derailment kerb to the height of rail. The team and I raised this issue with the designers, and an additional tolerance was negotiated, from 0 to 20mm.

The derailment tolerances were +5mm/-15mm, and the track height/superelevation was +/-5mm, admittedly, it made sense that our relative rail to kerb tolerance was -20mm/+10mm, giving a range of 30mm difference. This caused issues a week prior to dynamic testing, and I engaged closely with the designers to explore further tolerances, and where possible, have an option to reduce the nominal HDPE pad to 15mm to +/-5mm. After significant discussion and determination on my part to have this issue prioritised, the designers agreed to give leniency on the tolerance of 0 to 25mm as it did not affect the workability or safety of running the metro trains on the viaduct.

3) Quality Checks

I completed quality checks at the commencement and completion of each shift, irrespective of whether I was on day or night shift. Day shift quality checks included checking warped pads and to follow up on the Megapoxy pour completed by the night shift crew. Due to the limited light support during the night, I had to ensure that the Megapoxy was filled to the bottom of the baseplates, those that settled required top ups during the day. Overall, the site team was averaging between 100 to 120 lineal meters over a 24-hour period, peaking at a total of 342 baseplates completed. Figure XXIII is an examples of the finished buffed pads.

FIGURE XXIII MEGAPOXY PADS

The sheer size and technical complexity of the project allowed me to experience multiple construction for the first time. This included the substantial baseplate assembly, pictured in Figure XXIV. Over the course of the works, I fixed 26,486 Alt 1 baseplates, and had used 172,159L of Megapoxy.

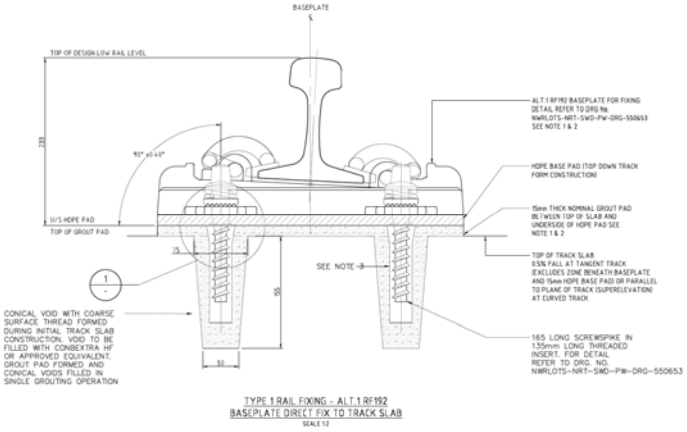

FIGURE XXIV TYPE 1 RAIL FIXING – ALT 1 RF192

H. Type 3 Track: Underline Crossing (ULX)

The underline crossing (ULX) and expansion switch at WRB adopted a Type 3 track slab. There was no grout pad, and the screw spikes on the baseplate were casted into the concrete.

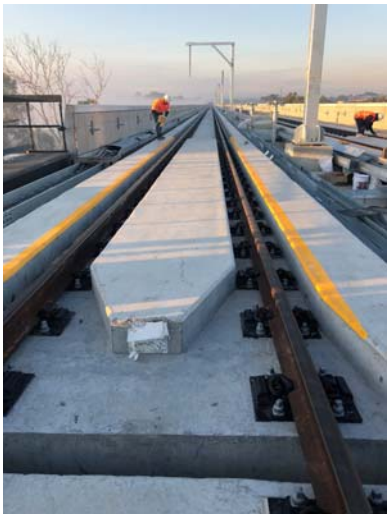

FIGURE XXV ULX

I. Expansion Switch

The expansion switch spanned for 12m on each track and was designed to accommodate the expansion and contraction of the cable stay WRB. There were many factors that went into the construction methodology. Like a turnout, the expansion switch has much bigger and heavier baseplates (a Delkor 300mm egg plate) and additional top-down equipment was designed and fabricated to accommodate for this, including the development for what we dubbed the 'pony', shown in Figure XXVI.

The pony is similar to the iron horses; it has the 1:20 cant casted into the design, but does not allow gauge to be held

between the switches. Gauge bars were designed and manufactured as a separate component so ponies could withstand heavier plates. As the expansion switch adopted the top-down methodology, the spindles were significantly longer in the ponies and existing push pulls, allowing for adjustment to the vertical and horizontal alignment to design. It was necessary for the Project Engineer and I to get the exact measurements of where we wanted the ponies positioned in the expansion switch due to the varying width dimensions. Measurements were taken and a tolerance of +2mm was added to ensure that the ponies fit where we had intended, spaced at every 2.1m. Baseplate covers were also designed and fabricated to reduce the concrete splashing onto the baseplate.

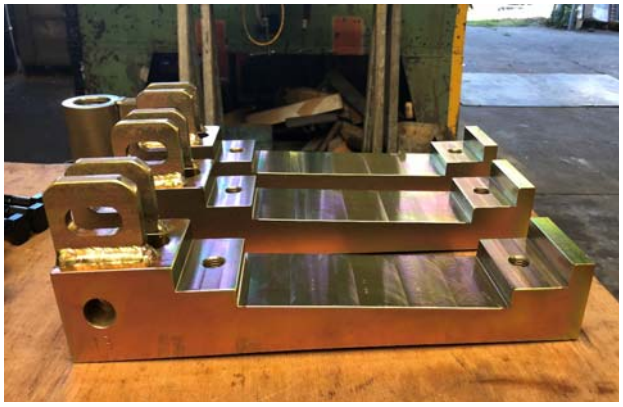

FIGURE XXVI EXPANSION SWITCH PONY

The concrete was casted when the bridge was at neutral temperature to ensure the expansion switch points were squared and lined to design horizontal and vertical alignment. This was quite difficult as there wasn't a clear indication of where the switch point was located. It was later determined with the supplier that the centre of the bolt, of the first plate away from the switch top in the direction of travel was adopted for the switch point and reference point for squareness. This is better explained in Figure XXVII, where the red line through the baseplates indicates the point of reference.

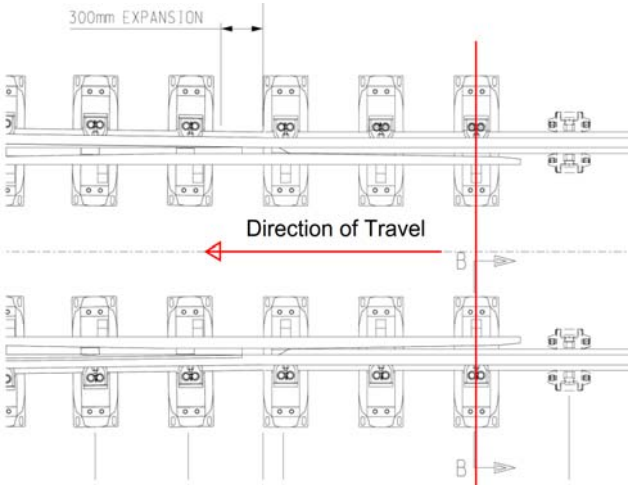

FIGURE XXVII EXPANSION SWITCH POINT OF REFERENCE

Aluminotheric welding of the expansion switch was a very significant challenge due to the moving bridge and temperature of the rail. Typically, the expansion switch would be welded out at neutral temperature of the rail to avoid any steel buckling. As the expansion switch was the final rail component on the viaduct to be installed, welding and adjusting of Continuous Welded Rail (CWR) was already completed on the remaining portion of the viaduct.

I consulted with the designers onsite to support the resolution of this issue. Traditionally, the expansion joints need to be treated as fixed locations, similar to a turnout. In this case part of the anchor lengths for the adjacent adjustments.

Down Track:

45km 254 to 45km 326 = 72m

45km 343 to 45km 395 = 52m

Up Track

45km 297 to 45km 322 = 25m

45km 332 to 45km 392 = 60m

The expansion joints are welded into track at a later stage such that they only accommodate the movement of the bridge, but also cater for any relative displacement between the bridge and rails (through the unadjusted anchor lengths), due to the thermal variations, train braking and traction forces. At the time discussed with the designers, we had set the expansion joint with reference to the bridge neutral temperature of 24°C and expected a period of "settlement" while the bridge and track slab concrete cured, and as the tracks are subject to traffic loads during train testing.

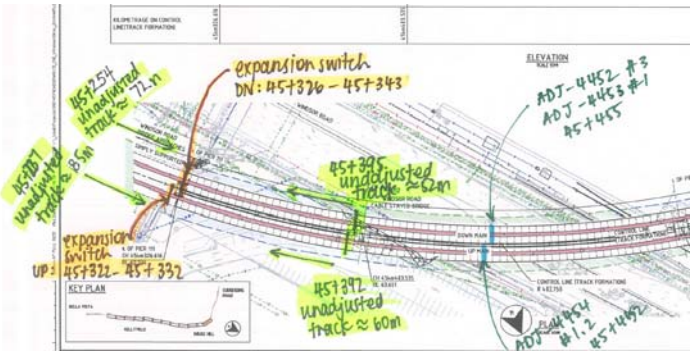

FIGURE XXVIII ADJUSTMENT PLAN OF EXPANSION SWITCH

J. *Ballasted Track*

The viaduct design package included two at-grade sections of track work. There was approximately 840m of ballasted track between SPC viaduct and WRB viaduct (Portion H), and approximately 1.7km between the tunnel entrance at Bella Vista Station and the start of the Viaduct (Portion 2/Bella Vista Cutting). Modification to the existing scope was added to extend the Sydney Metro Transit Facility (better known as SMTF or the Stabling Yard) at a later stage, in readiness for future works in the Line-Wide contract. This additional scope was later known as MOD66 and consisted of constructing a diamond and 7 new turnouts.

Typically, the civils team would build the formation/capping layer and hand it over to the track team to complete the track build. However, due to the overwhelming scope of the civils team at the time, it was best suited for the track team and I to construct this. Completing this scope in-house gave us full control over the quality and attention to detail of the capping layer and allowed works to be tied into the program accordingly without causing handover delays. It was important for the formation to be built in suitable weather conditions as wet weather would affect the proof rolling, compaction tests and the overall workability and quality which could potentially cause the track to sink.

K. Plain Line Track

I ensured the scope was programmed accordingly to suit the greater needs of the project, and those of the individual work groups to coordinate entry onto site, until the track was built to allow hi-rail machines.

The plain line track at Portion H was the first to be built at the end of 2017, where the up track was prioritised to ensure road vehicles and plant machinery could access the SPC viaduct and WRB viaduct from the access ramp. As the overall viaduct scope was constructed in stages, the plain line track was built shy of WRB by 20-30m to allow the rails to be married up at a later date.

Equipment used included the drott machine to lay bottom ballast to the correct height and level, a skid steer (bobcat) with spacers to ensure sleepers were spaced evenly every 600mm, and excavator/loader to ensure the rails were placed onto the sleepers without damaging them.

The Bella Vista cutting was constructed between March and April 2018 where the up track was prioritised to ensure road and hi-rail vehicles could access the tunnel and onto the viaduct. The Bella Vista cutting construction of 4 turnouts.

Maintaining effective communication was vital when working in the cutting to coordinate the multiple teams requiring access in and out of the viaduct and tunnel, as the cutting was the only access into the tunnel for almost 20km. To ensure this, daily meetings were held to maintain the planned program and coordination of activities. At these meetings, I was diligent in communicating the importance of maintaining track install activities as a top priority: until trackwork was completed, access and egress could not occur without ease.

L. Special Works – Turnouts and Diamond

The four 1:18.5 radius turnouts were installed on greenfield in the Bella Vista cutting, whereas the remaining 7 turnouts and diamond, a part of MOD66 was installed at SMTF in a brownfield.

MOD66 was highly challenging as the scope wasn't confirmed until a couple of weeks before construction commenced. A lot was involved in obtaining the correct permits to get on track, and resourcing additional support including labour hire, plant and machinery. It was important that I liaised with all work groups involved, especially the SMTF yard manager and the train movement manager. I developed and maintained strong professional relationships with subcontractors and my peers, and it was because of this that they supported me during MOD66, where I had a limited timeframe due to unconfirmed possession dates.

I was heavily involved with the methodology and planning for MOD66. As it was a brownfield construction, works were installed during a possession. The turnouts and diamond were pre-built, as shown in Figure XXIX. I learnt how to calculate and design a lift study and the importance of pre-building and taking critical measurements beforehand and match marking the rail to the base plates on the concrete bearers.

Dual lift with FEL was adopted to install 6 of the MOD66 turnouts. Pemlems were used to install a turnout due to the restricted access of machinery, where I worked closely with my Project Engineer to complete the lift study. The diamond and turnout were installed in a weekend possession. Each job step was detailed into the program per half hour. It was unfortunate that the steelwork supplier could not deliver all the diamond steelwork on time for this possession, however an executive decision was made to install it without the K crossing. Overall, with the high pressure and high profile of this possession, my team and I successfully delivered the modification works which entails 53 welds.

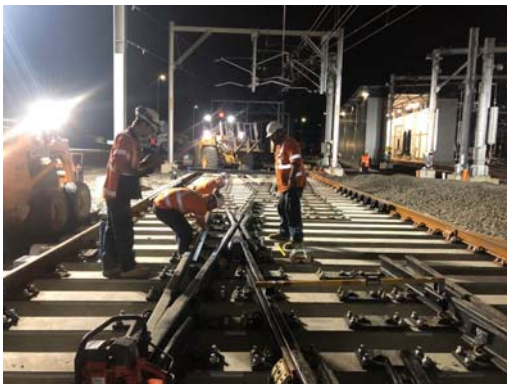

FIGURE XXIX MOD66 DIAMOND POSSESSION

FIGURE XXX COMPLETED DIAMOND

V. Conclusion

The Sydney Metro Northwest was a highly complex project wherein I was able to experience a number of Australian firsts, including the installation of track along a significant length of viaduct. The nature of the works within a highly constricted work footprint, while working under demanding deadlines and engaging with industry leaders and working closely with highly skilled and experienced rail personnel, was a unique experience that has meant my involvement in the project resulted in a meaningful contribution to a city-building project.

Design and experimentation of Permeable Pavement Systems at Western Sydney University

Upeka Kuruppu
School of Computing,
Engineering and Mathematics
Western Sydney University
Kingswood, Australia
u.kuruppu@westernsydney.edu.au

Ataur Rahman
School of Computing,
Engineering and Mathematics
Western Sydney University
Kingswood, Australia
a.rahman@westernsydney.edu.au

Arumugam Sathasivan
School of Computing,
Engineering and Mathematics
Western Sydney University
Kingswood, Australia
a.sathasivan@westernsydney.edu.au

***Abstract*—This paper presents designing and experimenting a pilot-scale Permeable Pavement Systems (PPSs) at Western Sydney University. Six PPSs columns with different subbase configurations were studied to evaluate the effect of different aggregate materials and subbase layer settings on water treatment performance of PPSs. A series of experiments were carried out using synthetic stormwater having different pollutant concentrations while maintaining varying rainfall intensities to simulate realistic rainfall-runoff conditions. These experiments were performed in controlled environments enabling to measure the effects of adding bark chips, saturated zone and thin sand layers in the subbase on the treatment of nutrients and heavy metals in the runoff. Synthetic stormwater utilised in the experiment enabled running duplicates and maintaining different pollutant concentrations to simulate typical runoff conditions. Stormwater treatment performances were tested for three different average rainfall intensities (20 mm/4hr, 40 mm/4hr and 120 mm/4hr). Experimental results support in establishing cause and effect relationships while allowing modifications to the PPS structure for its application in a wider urban environment as a component of sustainable urban planning.**

Keywords*—*PPS, stormwater, urban water cycle, WSUD

I. INTRODUCTION

In natural environments, rainfall is generally infiltrated into the ground, consumed by plants or evaporates back into the atmosphere. Urban development dramatically changes these processes, clearing land of vegetation and covering it with impervious surfaces that prevent water from infiltrating to the ground and create stormwater runoff. Industry, traffic and increased population in urban areas create high levels of pollutants that settle on impervious surfaces. These pollutants get mobilised with stormwater runoff and carried into the creeks and rivers. Water sensitive urban design (WSUD) is an approach for planning and designing urban areas to make use of this runoff as a resource and reduce the harm it can cause to the natural environment. WSUD principles aim to improve the ability of urban environments to capture, treat and re-use stormwater before it can pollute and degrade the natural habitat. With this green approach of stormwater management, permeable pavement systems (PPSs) are becoming more popular as a stormwater management tool. PPSs are porous pavements that can infiltrate stormwater quickly but retains some of the pollutants [1]. Many research studies have shown the ability of PPSs to substantially reduce runoff volumes and peak flows [2,3]. However, limited research can be found on improving the stormwater treatment performance of PPSs, in particular, for nitrogen attenuation.

The focus of the current research is to optimise the pollutant removal capacity of PPSs. This is going to be achieved by introducing design modifications and developing a computational model to predict the treatment performance of different PPS types. In particular, laboratory experiments are carried out to understand the chemical kinetics (e.g. reaction time and rate), suitable conditions (e.g. pH, temperature, redox potential and availability of oxygen) and necessary catalysts (e.g. microbes and cation exchange sites) required to optimise stormwater treatment processes in a PPS. These factors determine the practical applications of PPS with optimum conditions. This paper discusses the experimental setup and the water quality testing procedures applied at our experiment at Western Sydney University for achieving the above objectives.

II. OVERVIEW OF THE EXPERIMENT

A. *Experimental setup*

Model permeable pavement columns were constructed with different subbase configurations. Stormwater runoff through model PPSs was simulated by rainfall simulator using synthetic stormwater. Treated water was collected from the bottom of the columns and water quality was analysed in regular time intervals. This experiment was done for different rainfall intensities and durations. Six columns were constructed with different subbase settings shown as in Fig 1. Columns were constructed with an opaque material to simulate the natural conditions of PPS subbase. The column length (L = 600mm), width (W = 420mm) and height (H = 250mm) were taken based on the Representative Elementary Volume for porous media [4]. The inner wall of the columns was scratched to achieve a higher surface roughness in order to prevent preferential flow along the edge. The pan view of the PPS column setup has been presented in Fig 2 and the picture of the experimental setup has been presented in Fig 3.

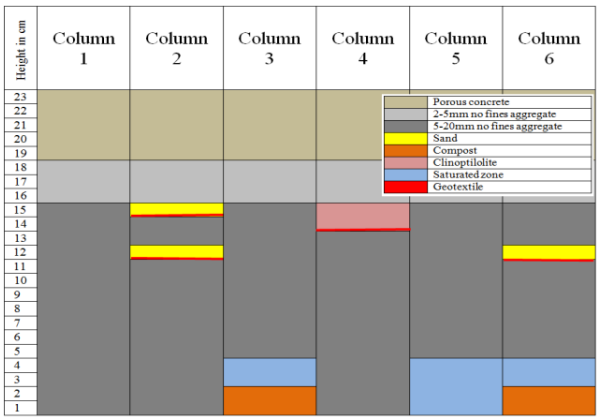

Fig 1: Colum cross-sections

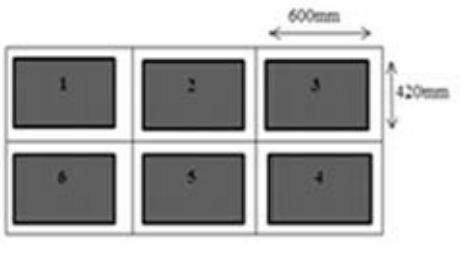

Fig 2: Plan view and the dimensions of the PPS column set up

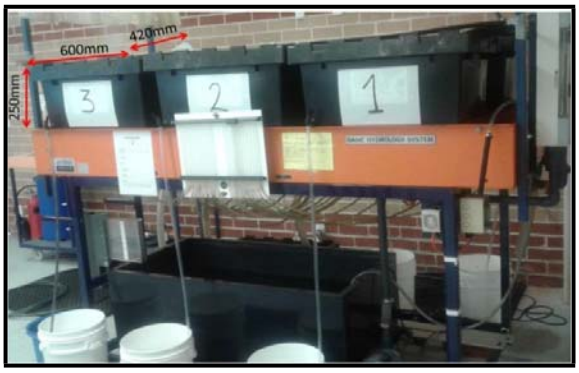

Fig 3: A picture of the experimental setup

B. *Simulation of stormwater runoff*

Since the pollutant levels in actual stormwater runoff vary during rainfall events, synthetic stormwater is being used for this experiment.

TABLE I. CHARACTERISTICS OF SYNTHESIZED STORMWATER

Parameter	Average concentrations (mg/L)
pH	5.5
Ammonical Nitrogen (Amm-N)	0.526
Nitrogen as Nitrites (NO_2- N)	0.505
Nitrogen as Nitrates (NO_3-N)	0.560
Total Inorganic Nitrogen (TIN-N)	1.591
Organic Carbon (Org – C)	3.68
Ba	0.223
Co	0.343
Cr	1.077
Mn	0.362
Pb	0.396
Al	0.325
Cu	0.755
Mo	0.662
Se	0.610
Sr	0.506
Ni	0.613
Zn	0.699
Fe	0.510

Synthetic stormwater composition – A mixture of hydrocarbons was dripped on to the surfaces. All other chemicals that comprised the synthetic stormwater solution were dissolved in dechlorinated tap water. Table I presents the characteristics of synthesized stormwater.

Three different rainfall intensities (20mm/4hr, 40mm/4hr and 120mm/4hr) have been simulated during the experiment. Rainfall duration was kept constant (4 hours) and samples were collected from all the six outlets every 15 minutes during 4 hours (16 samples in total per column). Experiments were repeated several times and mean readings were considered for data analysis.

III. WATER QUALITY TESTING

Linear polyethylene bottles were used for sampling. Containers and other consumables were thoroughly cleaned to avoid introducing contaminates to samples (washed using a metal and/or phosphorus-free detergent in tap water and rinsed with deionised water). Sample pre-treatments were done before preserving samples for subsequent analysis [5]. Samples were filtered through a 0.45-µm filter at the time of collection and the liquid phase was then preserved accordingly. Relevant digestion was done to make all the elements in soluble phase when it is needed to analyse total concentrations. Two levels of quality control samples were run after each calibration, every time new reagent vials were used with sample loads. Six calibration standards (diluted with distilled water), which were treated as same as samples, were used for calibration. In instrumental analysis (ex: ICP-OES), recalibration was done after every 10 samples.

A. Analysis of total solids (TS)

Principle: A well-mixed sample was evaporated in a weighted beaker and dried to a constant weight in an oven at 103ºC – 105ºC. The increase in weight over that of the empty beaker was taken as the total solids.

Procedure: Pyrex beakers were cleaned and heated in an oven at 103ºC to 105ºC for 1-hour and then stored and cooled in a desiccator (which contains a colour indicator for moisture concentration). Then they were taken out from the desiccator and the weight of each was measured before using. Samples were mixed in a magnetic stirrer. While mixing, 100ml of the well-mixed sample was transferred to the pre-weighted evaporating beaker using wide-bore pipette from the approximate midpoint of the beaker (at midway between beaker wall and vortex). The collected samples were set to evaporate in a drying oven at 98ºC (below boiling point for preventing splattering). Then the samples were further dried in the oven at 103ºC-105ºC. Then the samples were cooled in a desiccator and weighed. Drying, cooling, desiccating and weighing cycles were repeated till constant weight measurements of the samples were achieved. Sample duplicates were analysed for quality assurance. TS was calculated using equation 1:

$$\text{TS} = \frac{\text{weight of dried residue(mg)}}{\text{Sample volume(L)}} \qquad (1)$$

B. Analysis of total dissolved solids (TDS)

Principle: A well-mixed sample was filtered through a standard glass fiber filter, and the filtrate was allowed to evaporate in a weighted beaker, and then was dried at 180ºC. The increase in weight was measured as the TDS.

Procedure: Pyrex beakers were cleaned and heated in an oven at 180ºC for 1-hour and then cooled in a desiccator. Then they were taken out from the desiccator and the weight of each beaker was measured before using. Glass fiber filter disk (< 2um, no organic binder) was inserted to the cleaned filtration apparatus and it was washed with 20 mL of reagent grade water three times with applied vacuum. Samples were mixed in a magnetic stirrer. While mixing 100mL volume of the well-mixed sample was transferred to the filtering apparatus with applied vacuum. After filtration, filter disk was washed using 10ml of reagent grade water three times. Suction was continued for 3 minutes after the filtration to drain all the dissolved mater into the filtrate. The total filtrate was transferred to weighted beakers and evaporated in an oven at about 98ºC. Then the samples were dried in an oven at 180ºC, cooled in a desiccator and the weight was measured. Drying, cooling, desiccating and weighing cycles were repeated till constant weight measurements were achieved. TDS was calculated using equation 2.

$$\text{TDS} = \frac{\text{weight of dried residue(mg)}}{\text{Sample volume(L)}} \qquad (2)$$

C. Analysis of total suspended solids (TSS)

Principle: A well-mixed sample was filtered through a standard glass fiber filter, and residue remaining on the filter was dried to constant weight at 180ºC. The increase in weight was measured as the TSS.

Procedure: Glass fiber filter disk was inserted to the cleaned filtration apparatus and it was washed with 20 mL of reagent grade water three times with applied vacuum. Then the filters were dried in an oven at 103ºC – 105ºC, cooled in a desiccator and the weight was measured. Drying, cooling, desiccating and weighing cycles were repeated till constant weight measurements were received. Filter was inserted into the cleaned filtration apparatus and a small amount of reagent grade water was drained to seat it. Samples were mixed in a magnetic stirrer. While mixing 100mL volume of the well-mixed sample was transferred to the filtering apparatus with applied vacuum. After filtration, filter disk was washed using 10ml of reagent grade water three times. Suction was continued for 3 minutes after the filtration to drain all the dissolved mater into the filtrate. Filters with the residue were dried in an oven at 103ºC-105ºC, cooled in a desiccator and measured the weight. Drying, cooling, desiccating and weighing cycles were repeated till constant weight measurements were achieved. TSS was calculated using equation 3.

$$\text{TSS} = \frac{\text{weight of dried residue(mg)}}{\text{Sample volume(L)}} \qquad (3)$$

D. Analysis of Phosphorus

Phosphorus (P) presents in water almost solely as phosphates. Phosphates in water can be found in 3 forms (as orthophosphates or reactive phosphates (RP), condensed phosphates (polyphosphates) (PP), organically bound phosphates (OP)) and it can be in dissolved or suspended state.

The phosphorous analysis was done in two steps as

follows,

1. Convert all phosphate forms to orthophosphates
2. Colorimetric determination of dissolved orthophosphate

For dissolved phosphorus measurements, samples were filtered (through 0.45um) immediately after collection. Membrane filters were cleaned before filtration as they can contribute phosphorus to samples (50 filters were soaked in 2L of distilled water for 24 hours). H_2SO_4 or HCl was added to get the pH< 2 and stored at 4ºC. Glass containers (rinsed with diluted HCl and then rinsed several times in reagent grade water) were used for storing samples.

Digestion method: Persulphate oxidation was done to convert all the phosphorus forms to orthophosphates. Digestion was done to all the samples as well as to calibration standards, which were used for the calibration. 0.05 mL of phenolphthalein indicator was added to 50 mL of the well-mixed sample. If a red colour developed, H_2SO_4 solution was added dropwise to discard the colour. Then 1 mL of H_2SO_4 and 0.5g of potassium persulphate (or 0.4g of ammonium persulphate) were added. Samples were boiled for 30-40 minutes (or till get a 10 mL of final volume) on a preheated hotplate. Then the samples were cooled and diluted to 30 mL with distilled water. 0.05 mL of phenolphthalein indicator was added to each sample. NaOH was added to neutralise to faint pink colour. Then sample was diluted to 100 mL with distilled water and mixed well.

Colorimetric determination: Thermofisher Gallery analyser was used to determine the reactive phosphorus in samples. (Low range method for P 0.8 ug/L to 1 mg/L and high range method for P < 10 mg/L)

Principle: An Orthophosphate ion reacts with ammonium molybdite and antimony potassium tartrate (catalyst) under acidic conditions to form a 12-molybdophosphathoric acid complex. The complex was then reduced with ascorbic acid to form a blue heteropoly compound. The absorbance of this compound was measured spectrometrically at wavelength 880 nm (or 660 nm) and was related to the phosphate concentration by means of a calibration curve.

Re-agents: Thermofished ready-to-use reagents (CDK984366 Phosphorous R1 and CDK984368 Phosphorous R2) were used as reagents. Reagents were stored at 2-8C.

R1 – Sulphuric acid (16.5%) + Antimony potassium tartrate (<= 1%) + Ammonium molybdite (<= 1%)

R2 – Ascorbic acid (<= 2%))

Calibration: Linear. Six calibration calibration standards (diluted with distilled water) which were digested as samples were used for the calibration.

E. Analysis of total oxidised nitrogen (TON)by colorimetric hydrazine method

Thermofisher Gallery analyser was used to determine the TON in samples. (Low range method for N 7.3 ug/L to 2.5 mg/L and high range method for N < 25 mg/L).

Principle: Nitrate was reduced to nitrite by hydrazine under alkaline conditions. Total nitrite ions were then reacted with sulphanilamide and N-1-napththylethylenediamine dihydrochloride under acidic conditions to form a pink azo-dye. Absorbance was measured at 540 nm and was related to the TON by means of a calibration curve.

Re-agents: Thermofished ready-to-use re-agents (CDK984369 TON R1, CDK984370 TON R2 and CDK984371 TON R3) were used as reagents. Reagents were stored at 2-8C.

R1 – Sodium hydroxide (0.8%)

R2 – Hydrazine (<=0.1%) + Copper Sulphate (<= 0.1%) + Zink Sulphate (<= 0.1%)

R3 – Phosphoric acid (9%) + Sulphanilamide (<= 1%) + NEDD (<= 0.0%)

Calibration: Linear or 2nd order polynomial calibration curve was used for the calibration. Six calibration standards (diluted with distilled water) which were digested as samples were used for the calibration.

Quality control: Two levels of quality control samples were run after each calibration, every time a new reagent vial was used and daily with sample loads.

F. Analysis of ammonia by colorimetric determination.

Colorimetric determination: Thermofisher Gallery analyser was used to determine the ammonia and ammonium ions in samples. (Low range method for P 1.3 ug/L to 1 mg/L and high range method for P < 10 mg/L)

Principle: Ammonia reacts with hypochlorite ions generated by the alkaline hydrolysis of sodium di chloroisocyanurate to form monochloramine. This reacts with salicylate ions in the presence of sodium nitroprusside at around pH 12.6 to form a blue compound. The absorbance of this compound was measured spectrophotometrically at the wavelength 660 nm and was related to the ammonia concentration by means of a calibration curve.

Re-agents: Thermofished ready-to-use reagents (CDK984362 Ammonia R1 and CDK984363 Ammonia R2) were used as reagents. Reagents will be stored at 2-8C.

R1 – Sodium salicylate (<= 15%) + Trisodium citrate (<= 15%) + Sodium nitroprusside (<= 0.1%)

R2 – Sodium hydroxide (3.2%) + Sodium Dichlorosocyanurate (<= 1%)

Calibration: Linear or 2nd order polynomial (both can be used). Six calibration standards (diluted with distilled water) which were digested as samples were used for the calibration.

G. *Total Nitrogen (TN)*

Persulphate oxidation (which has described for TP) was done to convert all the nitrogen forms to nitrates. Digestion was done to all the samples and calibration standards. Thermofisher Gallery analyser was used to determine the nitrate (which is TN) in digested samples.

H. *Analysis of Metals*

Total metals: Metals can present in water organically and inorganically bound and both dissolved and particulate.

Samples were preserved immediately after by acidifying by high purity concentrated nitric acid to pH < 2 (added 5 mL of HNO_3 to 1L of sample) and stored at 4°C till they analyse (kept at least 16 hours before digestion).

Method: instrumental analysis, Shimadzu inductively coupled plasma - optical emission spectrometry (ICP-OES) 710 was used for metal analysis.

Principle: When plasma energy is given to an analysis sample from outside, the component elements (atoms) are excited. When the excited atoms return to low energy position, emission rays (spectrum rays) are released and the emission rays that correspond to the photon wavelength are measured. The element type is determined based on the position of the photon rays, and the content of each element is determined based on the intensity of the rays. To generate plasma, first, argon gas is supplied to torch coil, and high-frequency electric current is applied to the work coil at the tip of the torch tube. Using the electromagnetic field created in the torch tube by the high-frequency current, argon gas is ionized and plasma is generated. This plasma has high electron density and temperature (10000K) and this energy is used in the excitation-emission of the sample. Solution samples are introduced into the plasma in an atomized state through the narrow tube in the center of the torch tube.

IV. Results and Discussion

The overall stormwater treatment performance of six columns for 40mm/4hr rainfall intensity has been presented in Table II and Fig 3. The influence of rainfall intensity on pollutant attenuation is presented in Table III. Results indicate that permeable pavement with an organic carbon source and a saturated zone can significantly improve the stormwater quality during small to medium rainfall intensities (up to 40 mm per hour). Detailed experimental results of this study have been published in Jurnal and conference papers [6, 7, 8].

TABLE II. METAL ATTENUATION PERFORMANCE OF SIX COLUMNS

Metal	Inlet/ (mg/L)	Outlets / (mg/L)					
		Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Ba	0.223	0.009	0.008	0.016	0.009	0.008	0.001
Co	0.343	0.001	0.002	0.008	0	0	0.002
Cr	1.077	0.476	0.324	0.469	0.478	0.333	0.248
Mn	0.362	0	0	0.021	0	0.011	0.009
Pb	0.396	0	0.004	0.012	0.007	0.013	0
Al	0.325	0.009	0	0.016	0.014	0.011	0.004
Cu	0.755	0.009	0	0.017	0.005	0.192	0.008
Mo	0.662	0.274	0.184	0.522	0.277	0.125	0.14
Se	0.61	0.191	0.096	0.242	0.191	0.133	0.102
Sr	0.506	0.168	0.127	0.195	0.203	0.012	0.187
Ni	0.613	0.014	0.008	0.023	0.012	0.002	0.013
Zn	0.699	0.001	0	0.007	0.001	0.002	0.003
Fe	0.51	0.002	0	0.017	0.005	0.004	0.005
Total	**7.081**	**1.154**	**0.753**	**1.565**	**1.202**	**0.846**	**0.722**

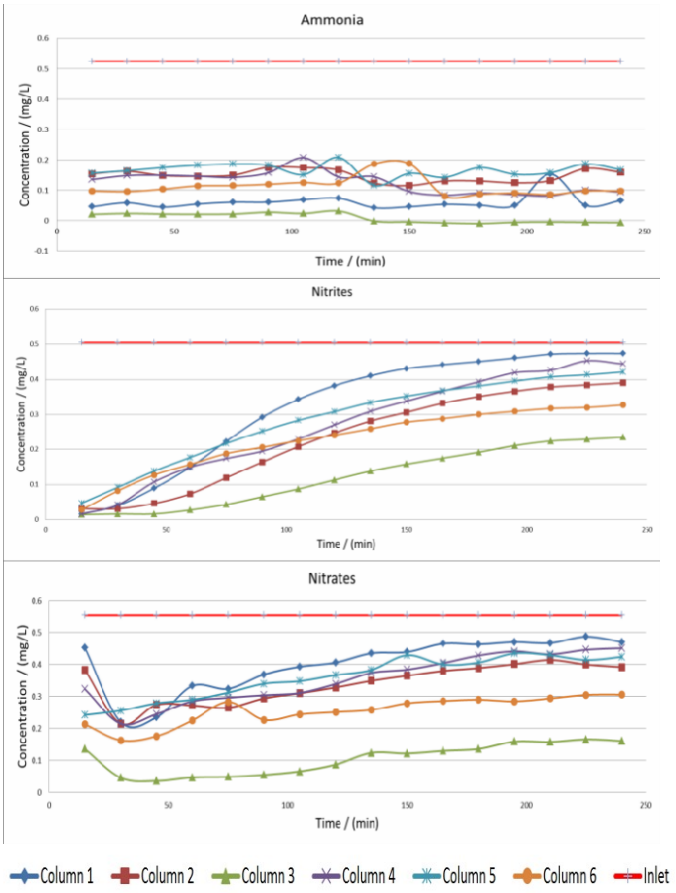

FIG 3: NITROGEN ATTENUATION PERFORMANCE OF SIX COLUMNS

TABLE III. METAL ATTENUATION PERFORMANCE OF SIX COLUMNS

	Percentage reduction for different average rainfall intensities (mm/ 4 hrs)		
	20	40	120
Column 1	88.77	62.19	13.07
Column 2	85.92	65.10	16.13
Column 3	95.69	90.85	16.90
Column 4	81.06	61.44	18.90
Column 5	84.20	55.57	15.24
Column 6	87.51	71.09	22.19

V. CONCLUSION

The experimental setup and the water quality testing procedures which have been discussed in this paper were adequate to obtain meaningful results and propose modifications to standard PPS structure for improved stormwater treatment performance. The experimental results confirmed the possibility of achieving improved pollutant attenuation by maintaining a saturated zone, a thin sand layer and incorporating an organic carbon source in the subbase of the pavement structure. Compared with the standard/traditional permeable pavements, the modified structure was able to attenuate twice the amount of pollutants in stormwater runoff. During the permeable pavement design stage, factors such as material selection and layer setting of the pavement structure need to be carefully considered to obtain the desired performance under the design rainfall condition of the proposed site.

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Flood Data Preparation in Eastern Australia: A Project Based Learning Exercise

Laura Rima
School of Computing, Engineering and Mathematics
Western Sydney University
Sydney, Australia
19274818@student.westernsydney.edu.au

Abhishek Gurung
School of Computing, Engineering and Mathematics
Western Sydney University
Sydney, Australia
19469805@student.westernsydney.edu.au

Khaled Haddad
Environment and Infrastructure Division
Cumberland Council
Sydney, Australia
khaled.haddad@cumberland.nsw.gov.au

Ataur Rahman
School of Computing, Engineering and Mathematics
Western Sydney University
Sydney, Australia
A.Rahman@westernsydney.edu.au

***Abstract*— Learning via projects is an effective method in engineering. In this paper, the implementation of a project and associated learning are presented. The project is part of a doctoral study of the first author, which involves collation and preparation of a quality controlled annual maximum flood (AMF) dataset to be used in a Regional Flood Frequency Analysis (RFFA) study. A total of 176 catchments from New South Wales (NSW), 195 catchments from Queensland (QLD) and 183 catchments from Victoria (VIC) are selected. Here, the AMF data were obtained from ARR Project 5 till 2011, which were then updated until the latest year available (2018). These AMF data have been checked by various descriptive statistics and diagnostics plots. Finally, GEV distribution has been applied to estimate flood quantiles for two stations. This will be repeated for all the selected stations, and will be used to develop a GEV distribution based RFFE technique for Australia. This paper also summarises the learning aspects from this engineering project.**

Keywords—streamflow, regional flood frequency analysis, data preparation, project-based learning, PhD study

I. INTRODUCTION

Project-based learning is an effective method in engineering education. In most of the doctoral research, data preparation is a primary step. In this paper, we present how data preparation project has been implemented in the doctoral study of the first author. This doctoral research project is on Regional Flood Frequency Analysis (RFFA).

To reduce flood damage, design flood estimation is required in hydrologic practice including design of hydraulic infrastructures (such as bridges and dams), floodplain management, development and planning controls, and flood insurance [8]. In addition, design flood needs to be precise at locations with no or poor streamflow data, as an overestimation would lead to a high cost of construction and an underestimation would lead to an increased flood damage.

At-site flood frequency analysis (FFA) is the preferred method of design flood estimation, which however requires a long period of recorded flood data to generate meaningful outcomes. Australia is a large continent where many catchments have poor/no streamflow data. In such cases, 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 [2]. In RFFA, flood characteristics information is transferred from gauged to ungauged catchments. RFFA uses flood data from nearby sites in a defined homogeneous region to make flood frequency estimation at ungauged sites of interest and estimate flood quantiles at any site within the region.

An RFFA method consists of three fundamental steps: data preparation; identification of homogeneous regions; and development of regional estimation models.

The collation and preparation of a quality controlled streamflow dataset is one of the major tasks in any RFFA as the quality and the size of the database can affect the accuracy of the quantile estimates. Generally, the bigger and higher quality the database, the more precise the estimates will be.

The main purpose of the data preparation in RFFA is to ensure that the annual maximum flood (AMF) data are accurate so the RFFA estimates are unbiased and have smaller uncertainty.

This paper presents a case study on AMF data preparation from 554 catchments from New South Wales (NSW), Queensland (QLD) and Victoria (VIC). Daily peak flood discharges of selected stations are downloaded from the websites of state water agencies. Afterward, AMF data were prepared (e.g. infilling the gaps), updated with the latest year available (2018) and saved in individual files. Finally, AMF data were prepared (average record length of 45 years), steps during data updating were presented and lessons learnt from this study are summarised.

II. AUSTRALIAN HYDROLOGY

The continent of Australia is situated in Oceania between the Indian Ocean and the South Pacific Ocean. It has a land area of almost 7.7 million km^2 making it the world's sixth largest country and the world's largest island.

Australia is the second-driest continent. It is also the lowest and flattest continent. It encompasses a large variety of climates with strong seasonal rainfall and temperature

variability. For example, in northern Australia, the climate is tropical which is characterised by warm temperatures, high humidity with a 'wet' season from November to April, where the region gets the most rainfall, and a 'dry' season from May to October. However, the southern part of the country has a temperate climate, and the interior part is arid/semi-arid. Moreover, rivers have potential changes in flow between wet and dry seasons due to seasonal rainfall variability in this area. Consequently, due to climate variability, Australia faces many of the most dangerous natural disasters such as floods, cyclones and bushfires similar to many other countries [9].

Australian Bureau of Meteorology (BOM) [1] stated that Australia's climate, as well as oceans around Australia, have warmed by around 1 °C since 1910. This warming has increased the frequency of extreme heat events and marine heatwaves. Also, the report showed the rising in sea levels around Australia, which may increase the flood risk. Moreover, rainfall and streamflow have decreased across southern Australia and increased across parts of northern Australia. As a result, climate change should be taken into consideration as it has a potential impact on flood risk analysis and water resource management.

III. Study Area and Data Preparation

Since eastern Australia has the highest density of stream gauging catchments with good quality streamflow data, this study focuses on this part of Australia. A total of 176 catchments have been selected from NSW, 183 catchments from VIC and 195 catchments from QLD. Most of these stations were used in the Australian Rainfall and Runoff (ARR) Project 5 [11]. Figures 1 and 2 present the geographical distribution of the selected catchments and the study area. The record lengths of AMF data series of these 557 stations range from 20 to 109 years. The catchment areas of the selected catchments range from 1 km^2 to 1,036 km^2.

Streamflow data have been updated with the latest data up to 2018. During the updating, several features of streamflow data gathering have been learned such as criteria of selection of the study catchments, checking AMF data series, filling of gaps in the AMF data series, examining the data for any significant trends, checking rating curve errors associated with the AMF and testing for outliers (both low and high outliers). Finally, the final set of stations are ready to be used in RFFA analysis. For each catchment, the corresponding gauging station information and catchment attributes should be extracted as well such as elevation, catchment centroid, catchment area, slope and forest.

IV. Data Sources

The streamflow data were obtained from the following:

- NSW streamflow data from the water NSW corporation. https://www.waternsw.com.au/waterinsights/real-time-data
- QLD streamflow data from Queensland Government, Department of Natural Resources, Mines and Energy (DNRME), water monitoring information portal (WMIP) service. https://water-monitoring.information.qld.gov.au
- VIC streamflow data from state government Victoria, the department of environment, land, water and planning, water measurement information system. http://data.water.vic.gov.au/

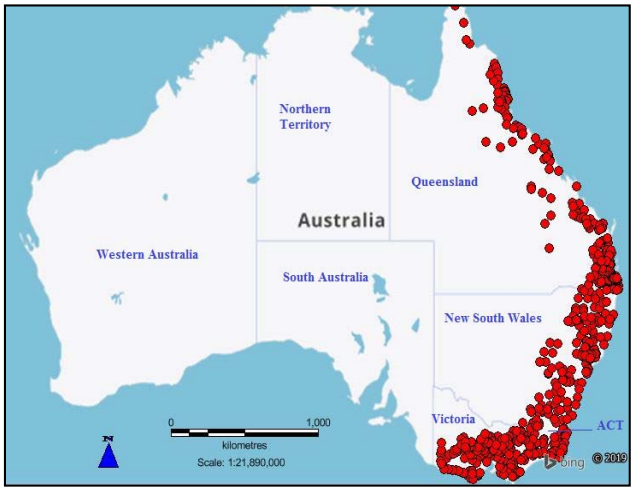

Fig. 1. Geographical distributions of the selected catchments in Queensland, Victoria and NSW, Australia

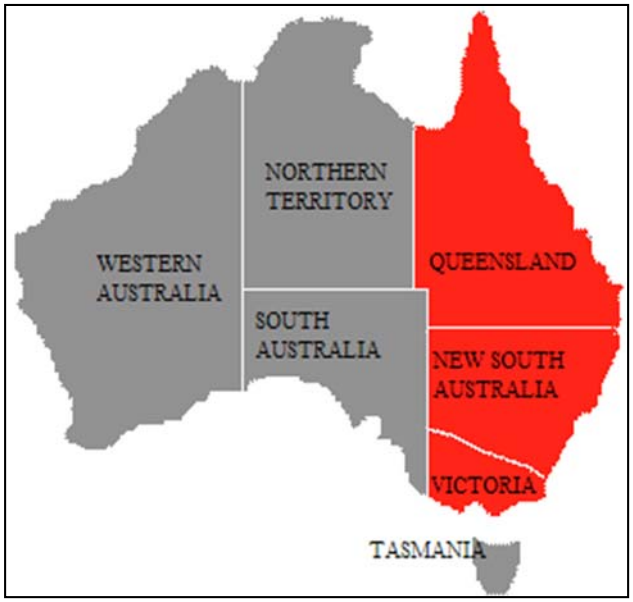

Fig. 2. Location of the selected study area (red parts of the map)

V. Criteria Adopted in Selection of Catchments

We adopted the following selection criteria as suggested by Haddad et al. [5] and ARR [11] and depicted in Figure 3:

- The catchment area to be small to medium sized with an upper limit of 1000 km^2.
- The streamflow record length at a stream gauging location should be minimum 25 years to enhance accuracy of at-site flood quantile estimates.
- The catchment is unimpaired, which is defined as having streamflow that is not subject to regulation or diversion, i.e. not subject to dam or reservoir regulation.
- The catchment should have no more than 10% of the area modified by urbanisation.

- Catchments should not have experienced large land use variations over the period of streamflow records.
- Most statistical flood data analysis assume that the available data are free of error. No poor quality data should be included.
- Climate variability and change: the impacts of climate variability present a serious problem as it may affect the AMF data series as well as the prediction of future flood frequency.

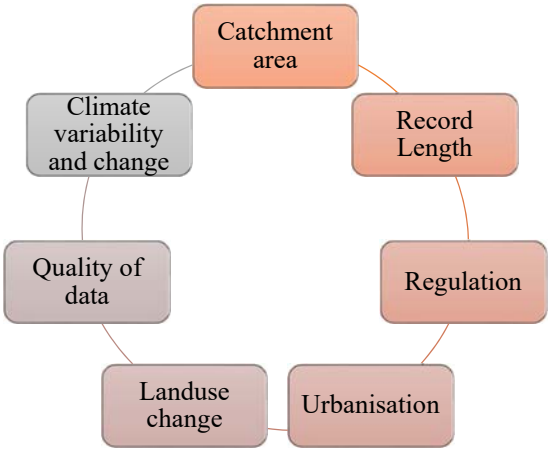

Fig. 3. Criteria adopted in selection of catchments

VI. Steps in Data Collation

The following steps present the detailed activities accomplished during data updating.

- Download the daily discharge Excel files from the relevant website.
- Calculate the maximum streamflow for each year and update the oldest AMF data series with the latest data up to 2018.
- Screen the streamflow data by checking for gross errors and making sure data are continuously available over time, i.e., there is no gap or missing record.
- Prepare an excel file including station name, start year, end year, record length, catchment area, and gaps.
- Write MATLAB program for doing exploratory data analysis.
- Calculate the summary statistics of AMF data, e.g., the minimum, maximum, mean, median, standard deviation, skew and coefficient of variation.
- Prepare histogram, mass curve and other plots of AMF data for each station in each of the states to visualise any significant error.

VII. Lessons Learnt

A. *Missing observations in streamflow records*

As per Haddad et al. [5] and Rahman et al. [10], it has been learned that there are two possible methods which can be applied to fill the missing observations in AMF flow records at a gauging location. The first method consists of comparing the monthly instantaneous maximum (IM) data with monthly maximum mean daily (MMD) data at the same station for years with data gaps. And the second method consists of using the developed linear regression equations (that relate the AMF data of the station in question and another nearby station) to infill the missing data points.

B. *Tests for outliers*

An outlier is an observation point that has a significant deviation from most of the other observations in the AMF data series. It might be due to variability in collecting and recording data or simply due to natural causes. Identification and treatment of low and high outliers are important steps in FFA because the presence of these outliers in the AMF data can introduce significant uncertainty in fitting a probability distribution using the available data and can highly affect the estimation of extreme flood quantiles.

The Grubbs-Beck test (GB) ([3] and [4]) can be adopted to treat high and low outliers in FFA by applying a one-sided 10% significance level criterion and detect a single outlier at a time, which cannot identify multiple outliers that may be present in the AMF data series.

Accordingly, Rahman et al. [12] examined two outliers' identification tests (GB and multiple GB (MGB)) and compared the performance of Log-Pearson III (LP3) and Generalised Extreme Value (GEV) distributions for six Australian catchments using FLIKE Software. They found that flood quantiles estimates derived from MGB with LP3 were more accurate than using GB with LP3. In addition, GEV and LP3 distributions provided similar results with the MGB test.

C. *Trend analysis*

Trend analysis is an important procedure for screening hydrological data to detect possible trends in the data. AMF data series should be tested to identify stations showing significant trends both increasing or decreasing in the mean of the data set.

According to Haddad et al. [5], two tests may to be applied to detect trends, the Mann–Kendall test [6] and the distribution free CUSUM test [7].

The Mann-Kendall test focuses in testing whether there is an increase or decrease in time series data, while the CUSUM test is concerned with testing whether the means in two parts of a data series are significantly different.

D. *Rating error analysis*

The reported AMF data at a given gauging site should be examined to identify the degree of extrapolation by calculating a 'rating ratio'. The rating ratio (RR) (see equation 1) is defined by dividing the AMF series data point at a specified station for each year (estimated flow Q_E) by the maximum measured flow (Q_M) for that station over the total period of record [10].

If the RR value is less than or near 1, the corresponding AMF data series can be considered as error-free in assessing the rating curve error [5]. However, if RR value is above 1, the corresponding AMF data series present a high degree of rating curve extrapolation error, which can affect the design flood estimates significantly [5].

$$RR = Q_E / Q_M \quad (1)$$

VIII. RESULTS AND DISCUSSION

After streamflow data collation for NSW, QLD and VIC till 2018, AMF data are checked by calculating the descriptive statistics of the AMF data and by using multiple plots such as histograms, time series plots and mass curves to detect visually if significant errors could be identified. Figures 4, 5, 6 and 7 present multiple plots for NSW and QLD stations.

Tables 1a, 1b and 1c present the descriptive statistics of the AMF data for seven stations from QLD (maximum, minimum, mean, median, standard deviation, skewness and the coefficient of variation).

We applied GEV distribution on two catchments in QLD using L-moment parameter estimation method. Tables 2a and 2b illustrate the results of L-moments and the three parameters (location, scale and shape) of the GEV distribution estimated for the selected stations from QLD. Then the quantiles for average recurrence interval (ARIs) of 2, 5, 10, 20, 50, 100, 200 and 500 years are estimated and presented in tables 3a and 3b.

TABLE 1A. EXAMPLE OF DESCRIPTIVE STATISTICS OF THE AMF DATA FOR SELECTED STATIONS FROM QLD

State: Queensland			
Station ID	***Min***	***Max***	***Mean***
102101	12.54	3559.29	1001.53
104001	142.72	1581.17	538.36
105105	19.31	719.53	288.73
105106	14.86	1915.28	508.48
107001	40.55	1355.74	339.46
107002	226.59	1042.84	702.15
108002	282.78	3529.02	1297.94

TABLE 1B. EXAMPLE OF DESCRIPTIVE STATISTICS OF THE AMF DATA FOR SELECTED STATIONS FROM QLD

State: Queensland				
Station ID	***Median***	***SD***	***Skew***	***CV***
102101	859.61	715.73	1.1774	0.7146
104001	441.19	357.26	1.0845	0.6636
105105	245.50	176.32	0.6309	0.6107
105106	352.95	499.27	1.6009	0.9819
107001	236.68	293.51	1.6970	0.8647
107002	724.35	231.04	-0.4133	0.3290
108002	1139.36	714.58	1.1405	0.5506

TABLE 1C. EXAMPLE OF DESCRIPTIVE STATISTICS OF THE AMF DATA FOR SELECTED STATIONS FROM QLD

State: Queensland				
Station ID	***State***	***Start Year***	***End Year***	***Record Length(years)***
102101	QLD	1968	2018	51
104001	QLD	1970	2018	49
105105	QLD	1970	2018	49
105106	QLD	1971	2005	35
107001	QLD	1959	2018	60
107002	QLD	1970	1989	20
108002	QLD	1969	2018	50

TABLE 2A. L-MOMENTS FOR TWO QLD STATIONS

State: Queensland			
Station ID	***LCV***	***LSkewness***	***LKurtosis***
102101	0.3886	0.2206	0.1320
104001	0.3605	0.2830	0.1046

TABLE 2B. GEV PARAMETERS FOR TWO QLD STATIONS

State: Queensland			
Station ID	***Shape***	***Scale***	***Location***
102101	-0.0777	519.77	658.45
104001	-0.1695	233.21	357.25

TABLE 3A. FLOOD QUANTILES ESTIMATION OF TWO QLD STATIONS IN THE RANGE OF Q_2 TO Q_{20} (Q IN M^3/S)

State: Queensland				
Station ID	***Q_2***	***Q_5***	***Q_{10}***	***Q_{20}***
102101	851.69	1485.34	1936.65	2395.00
104001	445.43	755.52	996.15	1257.56

TABLE 3B. FLOOD QUANTILES ESTIMATES OF TWO QLD STATIONS (Q_{50} - Q_{500}) (Q IN M^3/S)

State: Queensland				
Station ID	***Q_{50}***	***Q_{100}***	***Q_{200}***	***Q_{500}***
102101	3027.66	3532.71	4063.91	4810.15
104001	1646.93	1981.75	2357.17	2925.26

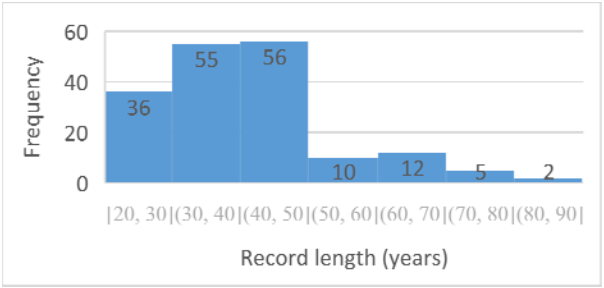

Fig.4. Distribution of streamflow record lengths of 176 stations from NSW

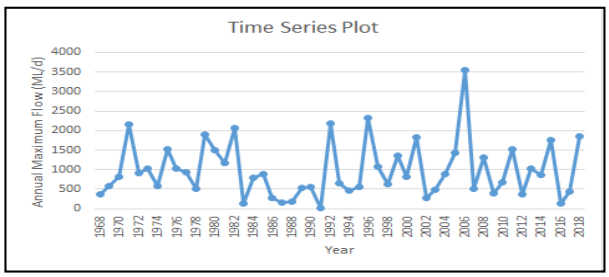

Fig. 5. Plot for time series for station 102101 in QLD

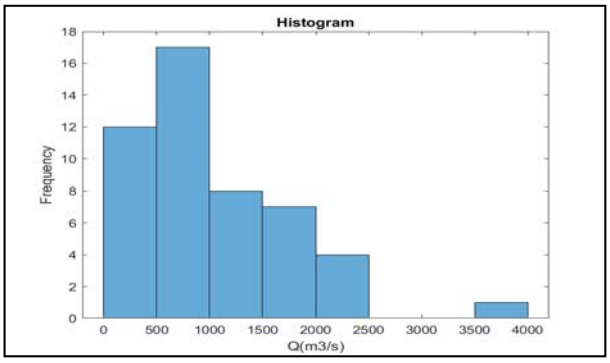

Fig. 6. Histogram for AMF for Station 102101 in QLD

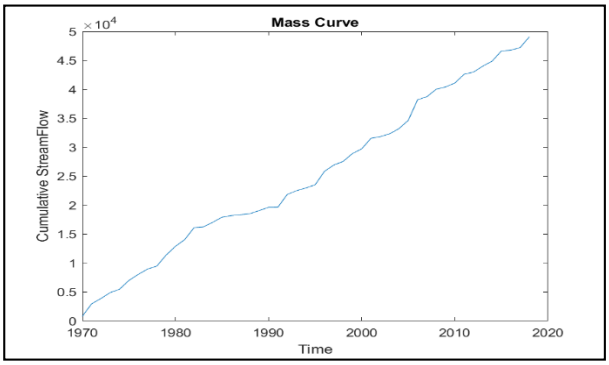

Fig.7. Plot for mass curve for AMF for Station 102101 in QLD

IX. CONCLUSION

This paper presents implementation of an engineering project as a part of a doctoral study. The project involved collation of annual maximum flood data for NSW, QLD and VIC states in Australia. The existing database from ARR Project 5 has been updated till 2018, i.e. for each of the stations we have more data, which should increase the accuracy of flood quantile estimates. The AMF data have been checked by exploratory data analysis. GEV and L moments methods are illustrated for two sample catchments to estimate flood quantiles for 2 to 500 years ARIs. This procedure is being repeated for the selected 554 catchments. The estimated flood quantiles will be used to develop a GEV-RFFE method for these three Australian states.

We learnt that streamflow data preparation needs significant project management skills including time management, regular group discussion, and quality control measures. A simple error in data preparation can influence the research outcome notably. The project has enhanced the learning skills of the first author in hydrology, which will be useful to her doctoral research and continuing education.

ACKNOWLEDGMENT

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A Scoping Review of Solar Stills Technology for Drinking Water Production

Elizabeth Myina Nomor[1], Rafiqul Islam[2], Ataur Rahman[3]
School of Engineering, Western Sydney University, New South Wales, Australia

[1]e.nomor@westernsydney.edu.au

Abstract*— Solar distillation is known to have low productivity. This paper ventures to investigate efforts by researchers to arrive at a breakthrough in obtaining higher yields in solar distillation. The performance of any solar still can only be judged by its resultant yield of distilled water. The common goal of researchers in the field is the optimisation of various parameters, in order to obtain higher still productivity. Optimisation of solar still performance has been attempted by manipulating the heat transfer processes of solar radiation reception, utilization by evaporation, condensation and noteworthy the capillary action that occurs between both. There is further scope to be explored on the enhancement of solar distillation stills as identified in this paper.

Keywords—solar stills, distillation, condensation, exergy, heat

I. INTRODUCTION

It is well known that more than 70% of the earth is covered by water [1]. However, more than 97% of this is salt water [2] and undrinkable. Clean drinking water is necessary for good health but unfortunately, most developing countries lack the economic capacity to afford water treatment facilities. The current estimates have at least two billion people, living without adequate amount of potable water [3].

Conventionally, potable water is obtainable by either filtration, chemical treatment, irradiation or distillation technologies. The first three require inputs either unavailable or too costly for some localities. Potable water can be obtained from brackish (saline), salty or stormwater sources from solar distillation units, via the processes of radiation, evaporation, capillary action, vapour transportation, condensation, conduction and convection [4]. These processes need control, based on a knowledge of influential parameters, to attain efficiency. Solar distillation offers a simple solution, with thermal processes typical to the earth's hydrological cycle.

During distillation, electro-magnetic waves carry heat from the sun [5] then radiate it unto the transparent cover of the still. Heat is received by the absorbent materials and water in the still, to evaporate a pure form of water from the basin and (due to a temperature difference) condense on the cover, inclined to aid downward flow of the purified water into a collector [6]. The brine which is left behind in the basin liner or floor, is composed of impurities.

II. LITERATURE REVIEW METHODOLOGY

The review peruses previous efforts by researchers on optimising key heat transfer processes so as to obtain a higher still yield. It attempts to magnify what aspects of these heat processes are relevant to efficient productivity. A literature search sought out high performing solar stills, with productivities greater than 10 L/m^{2}day.

A concise collection by [7], lists still productivities' and their corresponding areas. It highlights the disparity between size of still area and productivity, as shown in Fig. 2. This mentally elevates the existence of other influential factors or parameters that should be considered in the design inventions or technologies that would produce highly efficient stills.

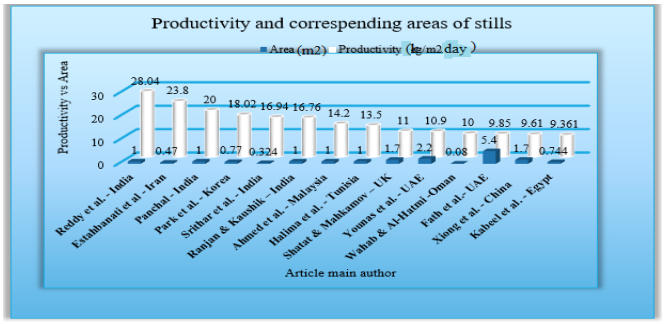

Figure 1. Non-correlation between still area and productivity

A survey of keywords from over eight hundred academic journals on solar still research between 2000 to 2019, using the Scopus database, was analysed using the software Vosviewer. This resulted in Fig. 2 below. Keywords like optimisation, productivity or efficiency had the highest co-occurrences in solar stills based literature. This gives a snapshot of popular interest in research focused on better still performance. Similarly, enhancements in the still for higher productivity also had a large presence. This emphasises that solar still based research is mainly focused on a search for breakthroughs on how to increase potable water yield.

Figure 2. A snapshot of keywords of solar still research

Capillary action is a phenomenon that if sufficiently researched for enhancement purposes, would open up opportunities for increasing the productivity of solar stills. With the use of various substrate materials in solar stills becoming popular, their respective pore sizes and thus capillary tubes play a vital role in determining the rate of evaporation flux [8]

A survey was carried out with Scopus database, to obtain the present number of literature that mentioned capillary action in relation to solar distillation. The results have been presented below in Fig. 3., showing only 9 journals so far, for a limitless period of publication. The peak year was 2018, with 3 journals.

Figure 3. A need for more literature addressing capillary action in solar stills

III. A CASE FOR SOLAR STILLS

Solar stills are very basic and require very low financing. They are environmentally sustainable, in that they are powered by green energy (solar). For the purpose of design and operations, no special skills are required for simple solar stills. There is also a possibility of constructing stills, using only locally obtained materials. In comparison, methods like chlorination have dosage specification, then follow-up stages of de-chlorination and also standard requirements for residually maintaining disinfection along the supply line [9]. Solar stills are the option with minimal need for larger capital investment, skill acquisition and degrees of precision that would be otherwise hazardous to health if not maintained. The required procedures for other methods are not only too complex but far-reaching for target communities. Some communities have large supplies of brackish water from the sea or harvested rain water to use as solar still feed.

The efficiency of stills is greatly affected by climatic factors like atmospheric vapour pressure, wind velocity and geographic location with respect to latitude [10]. Also vital to productivity are design factors like brine depth, inclination of cover, modifications like use of condensers, provision of larger condenser areas, absorbent materials and fins [11]. These give a boost to the distillate yield, when appropriately manipulated.

The major drawback for solar stills, is the low quantity of water produced. Since the supply of solar energy is limited to specific hours of the day, conventional production rates of water are 3 - 7 L/day with mean global radiation of 4 – 8 kWh/m^{2}day for 1 m^2 still area [12] and [13]. This review aims to identify how an increase of a solar still's performance or productivity is possible by optimizing the key thermal processes of evaporation, capillary action and condensation.

IV. HEAT PROCESSES IN DISTILLATION

Distillation occurs majorly due to the heat transfer processes of evaporation, capillary action and condensation [14]. They are phenomenal and have mass transfers which are net movements of water, occurring as gas or liquid [15]. While reviewing the optimisation of these processes, a basic understanding of exergy based performance of transient heat systems is necessary.

The work potential of a system based on the available energy, is its exergy [16]. To optimise the efficient use of supplied solar power unto the feed water for evaporation, the knowledge of the available exergy is essential. This would magnify how this supply is destroyed (used) or unconsumed as waste heat. The efficient use of available exergy can be attained via recycling the waste heat from either the evaporation or condensation chambers or even both. There are research opportunities as to how each mass transfer stage affects distillate output or makes good use of available exergy. The major quest for researchers, is how best these heat transfer processes can have their usually wasted heat energy, harnessed and recycled to warm up the inlet water feed. How can the supplied heat energy be engineered or insightfully manipulated, to reduce heat loss to the environment and enhance yield as the efficiency is boosted? As this is the pathway to produce higher yields of potable water.

Radiant energy as fuel, is received as electromagnetic waves by: (a) Using transparent covering for best reception [17] (b) Ensuring air tightness and insulation of still [18], to keep the absorbed heat from escaping to the ambient. (c) Utilising dark basin liners for optimum heat absorption [19] and (d) Inclining the basin covers, at angles directly facing sun rays [12].

Generally, radiation is measured as either horizontal or as inclined solar radiation, in kWh as "global horizontal irradiation" (GHI) and "direct normal irradiance" [20] [21]. This indicates the solar capacity of an area [22]. Australia has an annual average daily solar exposure range of 2.5 kWh/m^2 to 8.8 kWh/m^{2,}, one of the highest in the world [23].

It is essential to adequately manage available radiation in a location, so as to not only have optimum evaporation but also enhance higher levels of condensation on the surface over. This is either done by reducing the amount of radiation on the condensation surface or creating a separate chamber for condensation, which is not as exposed to the incoming insolation.

As a surface based phenomenon, evaporation occurs below the boiling temperature of a liquid, 100° Celsius for water. They are marked factors that increase the rate of evaporation in stills. These are presented below. The "light absorbing" and transportation properties of substrates (this is the absorptive material in a still) are essential to higher evaporation yields in the still [24]. These are biomimetic in structural designs to that experienced by plants, during transpiration. In transpiration, water is moved from the soil to other parts of the plant [25], similarly, this same mechanism moves vapour from the basin floor to its cover. A lot stands to be gained by studies that would enlarge this biological process and make inferences based on this natural concept. A study has experimented this out with solar steam generation [26].

Another developing area based on the properties of the basin material, is the use of nanometre sized particles, contained in a

base fluid and known as nano-fluids [27]. To achieve higher evaporation rates, their efficiencies depend on size, material, concentration in the base-fluids and volumetric flowrate of the resultant mixture [28].

To increase evaporation in stills, another major factor is solar insolation available in a location and that is absorbed by basin liner. This incident and absorbed heat must be enhanced to increase yield beyond conventional amount of 4-8 L/m^{2}day. Materials like jute cloth are used to increase surface area for solar heat absorption in a still [29], others are hot plate heaters [30], hollow pin fins heat sink and steel wool fibres [31], black tubes [32], various wick based materials and innovations [33] and reflectors [34]. During the operation of a solar still, use of drop-wise, spray or basin film feed are the options available [32]. The first two give room for better exposure to radiant heat and thus faster evaporation [35].

These stills introduce auxiliary sources of heat, like heat from steam powered engines [36]. To increase evaporation but are often ruled out in most cases because of the additional cost of incorporating them. Utilising rejected heat from evaporation should be the better and cheaper option, for attaining warmed up feed water for the still [37].

The optimum radiation necessary for evaporation should be a target area for research, since evaporation is a surface phenomenon and does not require heating up the entire water mass. The specific heat of vaporisation would be a good place to start, since it gives us an idea of just how much heat is required to vaporise water. This also would factor in the opposing process of condensation, which requires cooler temperatures but most at times occurs within the same still.

In distillation, mass transfers occur from liquid to gas phase (net evaporation) and from gas to liquid phase (condensation process). In between, is transportation of vapour from ongoing evaporation to the condensation phase in the solar still. This transfer occurs upward in the region between the water and the still cover, due to the capillary effect within the still [38].

Capillary action is the phenomenon responsible for sucking up water against gravity towards the sun's radiant heat [39]. This action provides added exposure of water to radiant energy [24] and is responsible for transport within the capillaries, as it vaporises [8]. The characteristic height and temperature of the capillaries, controls to a great extent, the rate of evaporation. Generally, the narrower the tube or pore of a substrate material, the easier it is for capillary action to be efficient, since surface tension is higher with [40]. These all point to the necessity for absorbent materials with narrower, shorter capillary structures, hydrophilicity and relative heat absorbency.

The capillary effect is responsible at a nanoscale, for what happens as the vapour rises from the surface of the water, through its medium of travel (air-space between cover and film of water). This air-space can be defined mainly by its humidity, enthalpy, temperature and vapour pressure. This stage affects evaporation and condensation [8].

Hydrophilicity (attraction to water molecules) is a key quality of materials ideal for aiding the capillary action in a solar still [41]. Some materials have water molecules more attracted to them than others [42]. Vapour rises as described above, it becomes the condensate or yield to be collected in the harvest stage of solar distillation. The condensate and not vapour is the major indicator of productivity and performance in solar stills. Naturally, condensation occurs on the coolest surface within the still, which is the lower surface of the cover.

Condensation is either "dropwise" or "filmwise" based on the degree of wetness exhibited by the cooled surface [43]. Dropwise when the condensation surface is partially covered but has droplets of water over it and filmwise when the entire surface is wet [43]. Studies by [44], discovered that the use of surfaces coated with nano-silicon solution, increased the wettability of the condensation surface and yielded more water. It can be inferred that filmwise condensation, is the preferred mode in solar stills for higher production.

Various efforts have been employed to enhance the condensation of stills, due to it requiring a lower temperature than other processes occurring in a still. These enhancements are primarily to aid the cover in rejecting latent heat, absorbed via radiation and convection [45]. This results to a cooler cover. Looking at a cooled surface as a goal for optimised condensation, it can be either provided artificially by incorporating chambers, heat exchanger or naturally [46]. Another way to look at it, is by considering condensation mimetically as well. Since nocturnally, condensation occurs naturally and effortlessly because of a cooled environment, the use of nocturnal cooling can be employed.

In an experimental study, a distillation unit was cooled by allowing it to float on seawater, with a separate condensation chamber lined with plastic bottom [41]. A recent design which utilises the incorporation of condensation phenomena based design, claimed 100% efficiency, recording a productivity of 2.20 L/m^{2}hr [47]. Heat from the environment, instead of direct solar irradiation was utilised, with an extra condensation chamber providing a conducive temperature for condensation. Glass thickness also impacts on condensation efficiency [48].

The Fig. 3 below highlights opportunities for performance optimization, via mass transfer during evaporation and condensation. These opportunities optional for each still, depending on design. This could be wasted heat from either evaporation or condensation, which can be collected and reused to heat the feed water.

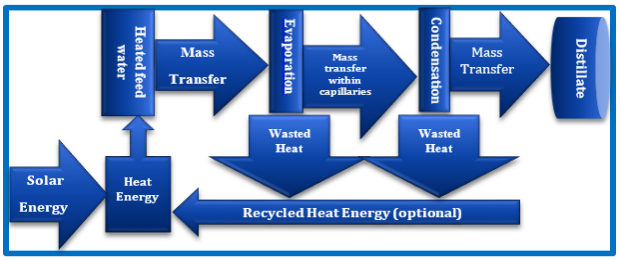

Figure 3. Key areas for harnessing heat loss in solar stills

V. Types of Solar Stills

Solar stills are either passive or active [49]. This classification is based on their mode of operation in regards to their use of radiant solar energy.

A. *Passive Stills*

Passive stills have no thermal energy harvesting or redirecting devices [50]. Their design, operation and maintenance is usually simple and ideally meet the needs of a wide range of users. They compose of a glass cover, basin with an absorptive liner (termed a blackbody), an insulating lagging material and the distillate collector.

Most passive stills use glass as the cover over the basin because it allows a lot of radiation energy, with minimal reflection [51]. The opposing processes of evaporation and condensation, occur within the still, under the lower surface of the glass cover. The "transmissivity" τgb, of the glass cover used, is dependent on the angle of solar incidence Θ, with the slope angle having an approximate value to the latitude [52].

The peak performance hour for most passive stills is 1 pm, with a production rate of 58 ml/hr at a 7.8 W/m^{2}day of solar radiation as recorded by [53]. This should as a result of the highest value of solar radiation being obtained in the previous hour (12 pm). They also recorded that, the water production rate is inversely proportional to the feed water depth. In this case, 1.5 cm depth (as compared with 2.5 cm and 5 cm) had higher heat absorption, as evaporation is usually higher at a lower volume of water. Passive stills are mostly conventional as stills designed for domestic uses, providing communities with the option of maintaining simplicity in solar still design, whilst catering for their basic need for clean water.

B. *Active Stills*

The optimisation of solar distillation process is a key to its continued attractiveness. It can be modified to maximise solar heat reception, storage and use. When this is done, an active solar still is said to be the result [54].

Generally, active stills are designed to increase heat flow and eventually still productivity. This is by increasing supply of solar energy while running or enables storage for continued operations during nocturnal hours. Devices like sun trackers [12], heat pumps [54], phase change materials, solar collectors [55], parabolic reflectors or concentrators [56] and heat exchangers [57].

The choice of modifications to be incorporated into an active still, is usually dependent on finding a balance between the intended cost, productivity and simplicity. Most at times, the cost of affording the additional devices for actively harvesting solar power might be too high. This might require the installation of devices like pumps to transfer the auxiliary heat into the system [58].

In recent times, active stills have gained attention, especially for large scale commercial desalination systems [59]. These plants are energy intensive and environmentally unsustainable, necessitating a search for renewable sources of power [60]. These include wind turbines [61], geothermal [62], thermocline energy [63], photovoltaics [64], solar ponds [65] and collectors [66].

Table I highlights the differences between passive and active solar stills. In conclusion, the downside for passive and active stills are still productivity and the cost of additional power on the environment respectively.

TABLE 1 PASSIVE VS ACTIVE STILLS

Passive Stills	Active Stills
Exclusive use of solar power	Auxiliary supply of thermal energy
Low water production	Higher water production rate
Conventional still design features	Additional devices to enhance heat transfer processes
Simple Construction and Operation	Might require complex technology for fabrication and operation

VI. Still Performance, Productivity and Efficiency

Design characteristics are to do with inbuilt solar still structure, modified to enhance performance, when compared to the conventional passive still. Operational factors are the still's properties while being run, like feed water rate and amount available in the basin. Ambient factors are both geographical and meteorological conditions. They are wind speed, humidity or ambient temperature of an area.

A. *Design Factors*

Domestic solar stills are designed to be prioritise simplicity or high performance [67]. To increase productivity, simplicity is compromised. Conventionally, the most prominent factors are:

a) *Inclination Angle of the Still Cover*

The angle of slope for the cover of the still impacts on the still's productivity with direct proportion [68]. With suggestions, that the glass cover inclination angle be equal to the location's latitude. The choice of what slope angle should be used for the cover of a still, is based on the target achievement of the following aims [69]:

A proper angle will position the still to receive *as much* solar radiation as possible. This would mean the angle that lets in the maximum amount of solar radiation directly unto the water mass. In most cases, the value for this angle hovers around the latitude for the experimental sight [70]. This is to give optimum exposure during the summer and winter periods. Unconventional shapes of stills like triangular and tubular designs, increase access to radiation, and are reported to have increased productivity. The glass angle reduces the reflection of incident solar radiation, minimising losses to the ambient.

B. *It ensures a safe collection of the product, forestalling any waste.*

a) *The Use of Phase Change Materials (P. C. M.)*

Phase change materials increase the absorption area for heat and provide latent heat banks solar stills to [71]. Copper and mica plates in the basin are ideal materials for increased heat transfer and thus productivity [50]. Solar reflectors and black dye gave a 25% increase in yield, when compared with conventional passive stills. Stepped type stills increased distillate quantity by increasing the water temperature, reducing a loss of the latent heat of condensation. A range of modifications using wicks, sponges and fins can increase productivity by up to 30%, 16.2% and 50% respectively. The storage of heat using black coloured materials like ink, dyes, gravel, rubber and charcoal, also gives better still yield.

b) Minimizing the Bottom and Side Losses

The bottom heat loss is that which occurs through the base of the still basin to the ambient. Generally, it should be minimised using quality insulation, especially for stills without phase change materials inserted in the basin liner [72].

Various materials like thermo-cool [18] have been used as insulation. The basin liner is the main heat bank, with a dark coloured material absorbing heat during the day and then releasing it during nocturnal hours. This heat can however be wasted to the ambient by inefficient lagging [17].

Stills are insulated at the bottom and sides, minimising heat loss through the basin liner or also from the water depth when being used as a storage for heat [73]. Common materials used as insulators in stills have low thermal conductivities like wood [74], sawdust [17], layers of thermo-cool [18], Polyurethane (PU) and polystyrene (PS) foams [75]. The heat loss coefficient of the sides is usually neglected if the still area is small [76].

C. Operational Factors

These factors participate in the functional aspects of the still. They are controllable and enhance the yield greatly. They include parameters like the water feed rate and depth in basin.

a) Minimizing the depth of the basin water

In order to increase the ongoing evaporation rate of a solar still, a difference in temperature between the inner surface of the glass cover over the still and water in the basin, is necessary. This difference in temperature drives still productivity [77]. The water depth has been established to be the most vital parameter for optimal distillation by [53], stipulating optimum depths ranging from 0.015 m to 0.03 m. This is irrespective of location. This is because the depth controls the heat sink capacity of the still, which is responsible for the required evaporation. The same author mentions the angle of tilt of the cover, intensity of solar radiation and ambient heat as also important factors for performance.

The water production rate is inversely proportional to the feed water depth. Mathematically, [53] presented this as equation 1.

$$Pd = 3.84–0.47dw \quad (1)$$

Where P_d is water production and d_w is the depth of water needing distillation.

A 1.5 cm depth (compared with 2.5 and 5 cm) had higher heat absorption, resulting to higher evaporation because of low water volume. This depends on duration as after more days, there would be better heat storage capacity and an experience of the benefits of nocturnal condensation [78].

b) Increasing the temperature difference between cover and water in basin

An ongoing temperature difference between cover and basin water drives distillation [53]. Since vapour transportation speed is driven by evaporation rate, which in turn is dependent on maximizing the basin temperature, and condensation is dependent on minimizing the condensation surface temperature. Sponges [38], wicks [79], fins [80], absorber plates [81], nanofluids [82], jute cloth [83], dark painted basin materials [81] have been used to increase the exposure of the still area to heat. A recent invention increases the system temperature by reusing evaporative energy, whilst cooling in the condensation chamber is kept below-room temperature in the entire system [47].

c) Ambient Factors

These are ambient air temperature, wind speed and relative humidity [10] as cited by [4].

d) Ambient Air Temperature

The ambient air temperature is dependent on the solar radiation over that area. Productivity reduces when the temperature of the ambient air is higher than that of the inlet water [84]. Evaporation rates are affected by the difference between basin water, air and cover temperatures [85]. The inlet water feed is influenced by ambient temperature.

e) Wind Speed

The wind velocity controls the cover's convective heat loss to the environment and condensation rate, giving the required temperature difference. Wind speed increases the energy efficiencies of stills [86], since this provides conducive coolness of the still cover for condensation [53]. A 50% increase in wind speed has been known to give more than 90% efficiency in distillate yield [87] and [11]. Other factors are solar intensity/duration, water depth, salinity of water, nature or materials used and the temperature of the still's components.

VII. CONCLUSION

This paper reviews water distillation by solar stills. It has been found that various parameters affect the productivity of stills, and investigations by researchers have grouped them as either design (modification for higher productivity), operational or ambient (climatic condition of location) [71]. Their control and enhancement could enhance the water yields of solar stills. Further research is required to appropriate a balance and hierarchy of relevance between these heat processes and other operating conditions.

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A preliminary study of light pollution in Sydney and the surrounding suburbs

Eresha H Chandrathilake
School of Engineering
Western Sydney University
Penrith, Australia
e.c.@westernsydney.edu.au

Ragbir Bhathal
School of Engineering
Western Sydney University
Penrith, Australia
r.bhathal@westernsydney.edu.au

***Abstract*—Over the last few years Sydney has been involved in major infrastructure, housing and high-rise building projects not only for residential but also for commercial uses including state of the art international airport. All these projects have been increasing the light pollution levels not only in the Sydney metropolitan area but also in the surrounding suburbs. This study investigates the severity of this light pollution.**

Keywords—Light pollution, night-sky brightness, sky heritage

I INTRODUCTION

This is a preliminary study to ascertain the light pollution levels ranging from Sydney's CBD t Wenthworth Falls about 78 km from Sydney were chosen to measure the Night Sky Brightness of light pollution levels. A seventh rural farmland location at Little Hartley about 175 kilometers from Sydney and at the foot of Mount Victoria in the Blue Mountains was studied as a reference point for this project. If one takes Little Hartley as the reference point the magnitude difference of light pollution between Sydney's CBS and Little Hartley was found to be 3.94 Mag/SqArcsec. The results from this study will be used to undertake a more comprehensive study of light pollution which will serve to provide a data base for NSW government's policy on light pollution and the need to introduce new regulations for acceptable levels of light pollution in the community and in the business sectors.

The introduction of artificial light was one of the most remarkable inventions in the history of humankind. It changed the way human beings conducted their lives when the Sun went down. The first electric street lamps appeared in Australia at Tamworth in Western Australia in 1886 while Sydney introduced them in 1904 [5]. LED lamps were installed in Sydney in 1962 [9]. The introduction of light bulbs led to the installation of outdoor lighting in the form of street lamps, bright lights at football stadiums and in advertising signs to sell products and events. The use of lights for outdoor lighting has increased exponentially over the last few years. Excessive illumination and poorly designed fixtures have led to a massive waste of energy and money. Sydney produced 4% more energy between 2016 and 2017. Od the 6145.8 Petajoules of energy consumed, 1692.7 Petajoules were used for electricity. This was 27.5% of all the energy used. It was the highest use of energy in the sector according to the Australian Government – Department of Environment and Energy [3]. A substantial amount of the electrical energy was used for outdoor lighting which adds to the light pollution in Sydney and its surroundings areas.

The International Dark Sky Association [6] defines light pollution as "The inappropriate or excessive use of artificial light" while the Rensselaer Polytechnic Institute [7] defines it as "An unwanted consequence of outdoor lighting. fixtures. Both definitions give a negative appraisal of badly designed outdoor lighting fixtures. The sky glow from the city of Sydney can still be seen over 70 kilometers away. Apart from the negative consequences of wastage of energy and money light pollution according to the American Medical Association has also been shown to have adverse effects not only on human health in terms of cardiac issues and cancer [1]

II LOSS OF SKY HERITAGE

The starry night sky has been observed by the Aboriginal and Torres Strait Islanders for thousands of years. They have not only named the stars but the stars are also part of their cultural heritage. Last year the International Astronomical Union recognized the Aboriginal names of the stars and included them in their catalogue of stars. Even as early as the 1920s Henry Chamberlain Russell, the Director of Sydney Observatory complained about the light pollution in Sydney [2]. With the rise of light pollution in the Sydney CBD the stars of the Southern Cross have faded. In fact, one can only see three rather than five stars. What is more disturbing is that the Milky Way Galaxy has not only lost its splendor but has virtually disappeared from the night sky. Future generations of young Australians have lost their home Galaxy.

III THE STUDY SITES

Information on the six data collection sites is given in Table 1. The data collection sites were, viz: Sydney Observatory in the CBD, Western Sydney University Parramatta Campus,

Western Sydney University Penrith Campus, Western Sydney University Campbelltown Observatory, Crago Observatory at Bowen Mountain and Lincolns Rock at Wentworth Falls. As a reference point a farming area at Little Hartley at the foot of Mount Victoria in the Blue Mountains was also added to the list because of its very dark sky in a rural area

TABLE I. Information on data collection sites

Site	Distance from Sydney CBD (km)	Height above sea level (km)	Population
Sydney Observatory	2	68	17,252
WSU Paramatta South Campus	18	19	25,311
WSU Campbelltown Rotary Observatory	44	262	12,566
Crago Observatory (Bowen Mountain)	64	152	1,571
Lincolns Rock (Wentworth Falls)	79	907	6,076
Little Hartley	150	820	536

IV METHOD AND INSTRUMENT USED

A Unihedron Sky Quality Meter [8] was used to carry out the measurements of the brightness of the night sky in units of magnitude per arc second square (mag arc^{-2}). A "magnitude"(mag) is a logarithmic scale unit used to measure the brightness of astronomical objects. A mag $arsec^{-2}$ can be converted into the more linear unit nano-Lamberts $(nL)^5$. which is commonly used by illumination engineers, through the relation $B = 34.08 \exp (20.7233 – 0.92104V)$ where B is the brightness measured in nL units and V is the brightness measured, in arc^{-2} [4]. The portability and ease of use of the SQM made it an ideal measurement device for data collection for this project. It employs a TAOS TSL237 high sensitivity light-to-frequency converter to capture information. The converter is protected by an infrared blocking Hoya CM-500 filter (Uni hedron 2019) This combination mimics the sensitivity of the human eye. The SQM has a half width half maximum (HWHM) of approximately 42^o.

In order to obtain accurate readings, the light sensor edge of the SQM was faced towards the zenith and the button on the front face of the SQM was pressed once. An audible beep indicated that a measurement was in progress. The narrow angular sensitivities of the SQM reduces the possibility of direct illumination from artificial light sources affecting the measurements. Readings were taken at least 20m away from the nearest street lamp or light source.

Readings for the project were taken every half hour from 6.00 pm to 10.00 pm. A low reading indicates a highly polluted area while a high reading indicates a less polluted area.

TABLE II. Light pollution levels

Time (pm)	Sydney Observatory	WSU Parramatta South Campus	WSU Campbelltown Rotary Observatory
6.00	8.28	8.73	10.95
6.30	12.65	12.56	11.50
7.00	17.10	15.96	16.32
7.30	17.28	16.64	17.12
8.00	17.32	16.68	17.23
8.30	17.40	17.08	17.67
9.00	17.54	17.28	17.80
9.30	17.82	17.68	17.97
10.00	17.89	17.70	18.14

Tables 2 and 3 give the results of the measurements and the light pollution levels at the sites that were studied. The average of five readings were recorded on two separate days at each location with a clear sky. Due to time constraints only six sites were used for this preliminary study over a two month period.

The results of the study clearly indicate that as one moves away from central Sydney the level of light pollution decreases. The main causes of the light pollution in the Central Business District are not just the street and vehicle lights but also the huge advertisement signs which are not static but have bright flashing lights to attract the attention of prospective customers. There has also recently been the custom to use bright LED lights. Light pollution has also increased in the Sydney CBD with the result of a large number of high-rise buildings.

Parramatta CBD is now suffering from the high-rise building syndrome as more and more high rise buildings are being built not only for commercial use but also for residential use as more new migrants make Parramatta their home due to proximity to jobs and services.

TABLE 3. Light pollution levels

Time (pm)	Bowen Mountain	Wentworth Falls	Little Hartley
6.00	10.01	9.89	10.12
6.30	16.08	15.09	16.81
7.00	19.42	18.31	19.33
7.30	19.32	18.34	19.92
8.00	20.45	20.40	21.42
8.30	20.88	20.81	21.84
9.00	20.88	20.83	21.95
9.30	20.89	20.87	22.15
10.00	21.00	20.91	22.21

Table 3 shows the results of the light pollution study from three areas over 60 km away from Sydney. Little Hartley is a country village with a low population of just about 500 people. Of the three country localities, Little Hartley has the lowest light pollution and it starts to get quite dark from about 8pm. Being located in the country area Bowen Mountain also enjoys fairly low light pollution levels. It was noticed that light glow from Sydney CBD is beginning to affect Little Hartley. Compared to 20 years ago the Milky Way at Little Hartley is beginning to fade.

V CONCLUSION

This preliminary study of light pollution in Sydney and its neighboring suburbs has revealed the severity of the light pollution that affects the Sydney and the Parramatta CBDs. It is imperative that both the Sydney and Parramatta City Councils need to carry out an extensive investigation of the light pollution levels and find ways and means of reducing it both for economic and heritage reasons. The night sky over these two areas is being lost to future generations of children and citizens.

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Addressing the Sustainable Development Goals: Roof Harvested Rainwater use in Household & Village Agriculture for Increased Nutrition and Education in Developing Nations: A Case Study of a Kenyan Orphanage

Caleb Christian Amos
School of Engineering
Western Sydney University
Sydney, Australia
c.amos@westernsydney.edu.au

Ataur Rahman
School of Engineering
Western Sydney University
Sydney, Australia
a.rahman@westernsydney.edu.au

Fazlul Karim
School of Engineering
CSIRO
ACT, Australia
Fazlul.Karim@csiro.au

John Mwangi Gathenya
Jomo Kenyatta University of
Agriculture & Technology,
Nairobi, Kenya
j.m.gathenya@jkuat.ac.ke

Eran Friedler
Faculty of Civ. & Env. Eng.
Technion- Israel Inst. of Technol.
Haifa, Israel
eranf@technion.ac.il

***Abstract*— Urban Agriculture, and particularly what may be termed household agriculture and village agriculture, has considerable potential to contribute to household nutrition, education and general well-being. Food is essential for survival, as recognized in United Nations' Sustainable Development Goal (SDG) 2, No Hunger and goal 3, Health and Wellbeing. Competition over water resources between agricultural and domestic use highlights an important nexus with goal 6, clean water and sanitation. Household agriculture can contribute to at least 8 of the 17 goals. Often home gardens fail due to lack of water and it has been found that roof harvested rainwater can help mitigate this issue. In this paper we model rainwater harvesting and potential food production using ERain, a daily climate data analysis tool. An established orphanage in Nakuru, Kenya that houses up to a maximum of 45 adults and 120 children is used for the study. A 1ML open reservoir with a rainwater inflow from a 1400m^2 roof catchment, and additional recycled water inflow of 8kL per day is currently used for irrigation of a 240m^2 greenhouse. Analyses showed that the irrigated greenhouse area could be increased eight times and still maintain 100% of water requirements. However if the recycled water is excluded, analysis indicates that the water requirements could currently only be met 74% of the time. If the reservoir was replaced with a closed tank to eliminate evaporation then a total of 500m^2 of greenhouse area or open field could be supported. It is emphasized that this is a multi-disciplinary issue and that education is essential to successful implementation.**

Keywords*— *Rainwater harvesting, Rainwater Storage Systems, urban agriculture, household agriculture, village, Sustainable Development Goals, Kenya

I. INTRODUCTION

More than enough food is already produced worldwide to feed everyone [1] – nevertheless, hunger remains due to the uneven distribution of that food. Household and village scale agriculture, a form of urban agriculture, has the advantage of being produced locally and by the intended consumers. Cuba was forced into producing a system that relied on neither diesel nor fertilizer due to trade embargo, and developed a system called organoponics, where the food is grown close to where it is consumed and organic material is used to fertilize garden beds. Cuba is now a world leader in urban agriculture [2]. In developing countries, urban agriculture is also growing in popularity [3]. The increase in urban agriculture implies an increase in water use, and so new sources of water need to be found. Australia, a very dry continent, has recognized the benefits of using rainwater harvesting to save water in gardens and instituted schemes such as the "Water Smart Gardens and Homes Rebate Scheme" [4]. Roof harvested rainwater shows considerable potential to support household and village scale agriculture to help provide important nutrition [5, 6] whilst also presenting a water saving potential [7, 8]. Although the concept of storing rainwater in dams and using it for agriculture is far from new, the use of roof harvested rainwater collection systems is not so common and there is generally a lack of research in this area [9]. With increased urbanization and modern building techniques in developing countries houses are becoming more suitable for rainwater

harvesting, for example through the use of tin roofs instead of grass or thatched roofs. Pollution from roof materials or from air pollution may mean it is not preferable for potable uses [10], using it in agriculture however avoids this issue. This is particularly relevant in arid and semi-arid areas where irrigation is necessary such as Nakuru, Kenya [11] where this study is focused.

Successful implementation of roof harvested rainwater use in household & village agriculture to meet household nutrition requires an understanding and appreciation of the multi-dimensional depth of the issue. The benefits of increasing the practice should also be appreciated. This can be demonstrated by the relationship to the sustainable development goals (SDGs). It can be shown that if it is approached as a multidisciplinary endeavor it directly contributes to at least 8 of the 17 SDGs. Most obviously it contributes to goal 2 zero hunger: *end hunger, achieve food security and improved nutrition and promote sustainable agriculture*, and goal 6 clean water and sanitation: *ensure availability and sustainable management of water and sanitation for all*. The practice of home gardening is also acknowledged to enhance wellbeing [12], and so relates to goal 3 good health and well-being: *ensure healthy lives and promote well-being for all at all ages*. Gardening is increasingly being used as an educational tool [13] and so relates to goal 4 quality education: *ensure inclusive and equitable quality education and promote lifelong learning opportunities for all*. By producing food close to the place of consumption, it reduces "food miles", and it contributes to greener cities and hence relates to both goal 11 sustainable cities and communities: *make cities and human settlements inclusive, safe, resilient and sustainable* and goal 12 responsible consumption and production: *ensure sustainable consumption and production patterns*. Also, since it is often the females who engage in home gardening as extra source of nutrition and or income to the household it also relates Goal 5 Gender Equality *Achieve gender equality and Empower all women and girls*. This is particularly true where culturally the women are responsible for fetching the water [14]. If the water is stored close to its point of use then this will save time, giving more time for education, and hence contributing to gender equality. Finally if by no more than increasing biodiversity of plants and insects [15] it relates to goal 15 life on land: *protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.*

Considering household and village scale agriculture and roof top rainwater harvestings in the context of these 8 goals can help structure a successful method for implementation. It is apparent that the mere construction of the systems will be far from adequate. Community education is essential for motivation and also for technical and agricultural knowledge to become common place in communities. Vegetable yields can vary considerably from a failed crop to high yields. A report of over 2600 yield expectations for small-scale agriculture [16] reported a yield range from less than half a kilogram to a maximum of 22 kg of vegetables per m^2 harvested. Poorly managed or resourced gardens will be considerably less productive. Soil quality of smaller gardens associated with households may be easier to improve with composts than large scale agriculture. Water resources and fertilizers are important, but also understanding what and when to plant, and the nutritional value, cultural acceptance and how to manage pests are all very important. Managing water resources and irrigation requirements also contributes significantly to yield. To be successful, household and village agriculture will require homeowners and villagers responsible for the gardens to become educated in these topics and so an education program will need to be part of the implementation strategy.

In this paper we focus on issues related to water management by analyzing the performance of an existing rainwater storage system (RSS) in an orphanage, Miti Ming Village in Nakuru, Kenya. A daily water balance analysis tool, ERain using daily climate data is used to do the analysis. It is a great pleasure to be using data provided by NASA in the year that marks the 50th anniversary of man on the moon (16th of July 1969) to address the basic needs of mankind in food and water. It reads as a dire lack that in the 50 years that have passed, and despite our technological advancements, that these basic issues remain. The issues of food and water are by no means absent from the recent UN sustainable development goals (SDGs) but feature quite prominently in goal's 2 and goal 6. Increasing competition over water resources between agricultural and domestic use highlights an important nexus between these goals. Having an existing scenario gives the advantage of identifying socio-economic and other multidisciplinary issues. It also gives an idea of what kind of systems can realistically be installed. The aim is that results can be put into a context that promotes realistic implementation of rainwater harvesting systems in developing countries where they can contribute to meeting the SDGs and be of benefit to local communities. It is hoped that the results of this research will be of particular interest to the Miti Mingi Village and may help in expanding their agricultural program.

II. Materials and Methods

Daily climate data were obtained from the NASA Langley Research Center POWER Project for the Miti Miti Village, Nakuru Kenya. Latitude -0.378, Longitude 36.186, elevation 1810m. This data were compared with averages for the region. Information about the circumstances at the orphanage were obtained from discussions with Sotheycan (Treadwell 2019), a charitable organization that promotes the principle that Education is the best route to sustainable change [17] and with the onsite Program Manager/Village Director, James Wabara (2019).

The orphanage can house up to 120 children and 45 adults at full capacity. There is no mains water available, and the two main water sources are rainwater and a bore. The bore is powered by mains electricity and yields up to 35 kL per day, which is pumped into an overhead tank (Figure 1c). Approximately 8 kL/day of the domestic water is recycled and stored in a 1000 kL reservoir (Figure 1a). The reservoir also has a roof catchment of 1400 m^2 flowing into it, and is analyzed both with and without the recycled water inflow to assess performance. It is uncovered and subject to evaporation losses which are modeled at 1.05 times the daily evapotranspiration (ETo) rate based on Allen, Pereira [18] assuming the reservoir depth is below 2m. The evaporable surface is 20 by 25m, or 500 m^2. A second tank of 225kL has a roof catchment of 800 m^2 is used to top up the overhead bore tank for domestic use if the bore fails. If both the bore and rainwater fail water must be purchased from the local water bowser and delivered by truck at cost of 4000 KSH (approximately AU$56) for 10kL. In this paper we focus on the 1000kL reservoir which is used to irrigate a 240m^2 of greenhouse crops. There is 4 acres of land available that could also potentially be irrigated.

The average amount of vegetables that can be produced per m^2 per year was chosen based on a study of 2,608 mixed stand community or home food gardens [16] and assuming 3 crops per year, at 7.3 kg/m^2/yr.

Fig. 1. A - 1000kL reservoir, B -greenhouse, C - overhead bore, D - 225kL water tank

Water use is determined based on the methods employed in FAO 56 [18], an average crop coefficient value (Kcb) of 1 is assumed for general vegetables. Evapotranspiration inside the greenhouse is taken as a conservative 0.75 times that outside, towards the upper limit given in Carolina and Eduardo [19].Scenarios for both greenhouse and open garden were considered. Values for daily fruit & vegetable consumption were taken as those advised by the World Health Organization (WHO) at 400g per adult per day, and assumed at 200g for smaller children [20]. This is compared to the Australian dietary guidelines [21]. Climate data was analyzed using ERain a daily analysis tool, the main elements of which are

- Yield after spillage rainwater harvesting system analysis
- FORTRAN data modelling
- R SCRIPT data presentation
- Daily Rainfall and climate data analysis
- Agricultural water use using FAO 56
- Crop production reduction FAO 33

The daily analysis model is based on the yield after spillage method of Fewkes and Butler [22], evapotranspiration and water use is based on FAO 56 [18], other details about the model development can be found in Amos et. al. [9, 23, 24].The method in FAO 33 [25] is used to determine the crop yield based on water supply.

III. Results and Discussion

Table 1 shows ERain rainwater storage system (RSS) performance results for greenhouse with recycled water of 8 kL per day and evaporation from reservoir storage included. Results show that there is plenty of water available to support all the irrigation needs of the current greenhouse of 240 m^2. Moreover, it can be seen that a much larger greenhouse area could be supported, potentially up to 2000 m^2. With larger areas however, the reliability reduces and hence the crop production per m^2 reduced drastically. Nevertheless, with careful management and seasonal planting a large area could be supported.

Due to the expense of greenhouses, the concept of irrigating open field gardens was also compared. Figures 2 & 3 show ERain rainwater storage performance for garden areas up to approx. 1 acre (4000 m^2), and 5 acres (20000 m^2) respectively. Scenarios include analysis for greenhouse (GH) and open field (OF), open reservoir (Evap), and including 8 kL per day of recycled water (Rcyl).

Figure 2 shows that without the additional 8kL/day of recycled water (GH_Evap), the open reservoir cannot fully support the current greenhouse, and reliability is at 74%. If evaporation was controlled however (GH) then a greenhouse twice the size (500 m^2) could be supported. The same reservoir with controlled evaporation could also support an open field (OF) irrigated area of 500-1000m^2.

TABLE I. ERain RSS performance results

Green-house Area	*Actual Crop Yield*	*Max Crop Yield*	*RSS Water Yield*	*RSS Reliability*	*Ave Crop Yield*
(m2)	*(kg)*	*(kg)*	*(kL)*	*(%)*	*(kg/(m^2*y))*
10	73	73	12	100	7.27
20	145	145	24	100	7.26
40	291	291	47	100	7.26
60	436	436	71	100	7.26
80	581	581	94	100	7.26
100	726	727	118	100	7.26
120	872	872	142	100	7.26
160	1162	1163	189	100	7.26
200	1453	1454	236	100	7.26
240	1744	1744	283	100	7.26
300	2179	2181	354	100	7.26
500	3632	3634	590	100	7.26
1000	7265	7269	1181	100	7.26
1500	10897	10903	1771	100	7.26
2000	14529	14537	2362	100	7.26
4000	17913	29074	2934	67	4.48
8000	16693	58149	2943	37	2.09
10000	15819	72686	2943	30	1.58
15000	13362	109029	2943	21	0.89
20000	10739	145372	2943	17	0.54

The current system (GH_Evap_Rcyl) could only support 17% of the irrigation needs of 20,000 m^2 of greenhouse (Figure 3). For open fields (OF_Evap_Rcyl) this is higher at 64% due to the rain falling on the plot. If the recycled water is not included this further reduces to 57% (OF_Evap). The almost horizontal line of the OF_Evap from 7500m^2 indicates that rainfed agriculture may support close to 57% of the water requirements for a year-round crop of general vegetables. Thus, the benefits of the RSS would be negligible for reliabilities below 60%. The viability of using a greenhouse should be considered. They have been promoted through various projects for ten years, but in some areas, they were not appropriate and many farmers stopped using them. Some areas in Kenya are so hot that greenhouses are a problem, not a solution. Shade nets may be more appropriate for warmer regions to help reduce evaporation and scorching and to control insects and pests. They would also have the advantage of allowing rain to fall on the cultivated land. RSS performance would therefore be similar to open field, if not better due to reduced evaporation from the shade. Greenhouses may still be viable in some areas and help protect heavy rainfall that can destroy cash crops [26]. A deeper understanding of water use in various types of greenhouses, and particularly those economically viable and appropriate to the area should be considered. Results here for the greenhouse may therefore be considered as indicative only.

Returning to table 1, it can be seen that if the annual yield per m^2 of 7.26 can be achieved, then a large greenhouse system of 2000m^2 could potentially supply 14530 kg of vegetables per year. Assuming that there are 100 adult portions of vegetables required for the orphanage, this is a total of 100 x 0.4kg x 365 days = 14600 kg. So such a system could theoretically support the orphanage's vegetable needs. According to Iannotti [27] at intermediate yields 200sqft or 18.5m^2 is required per person to grow enough vegetables and soft fruits for the growing season, for 100 people this would be 1850 m^2, which agrees quite well with the calculation here for 2000 m^2 cultivated area.

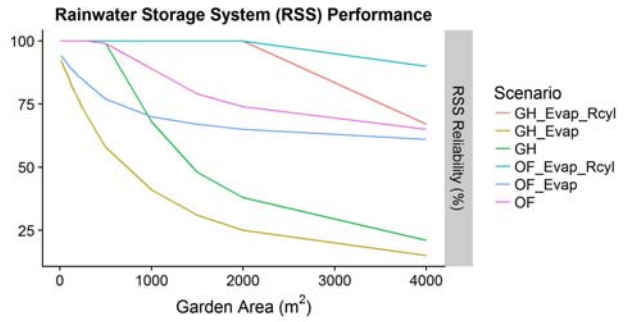

Fig. 2. Performance results for garden

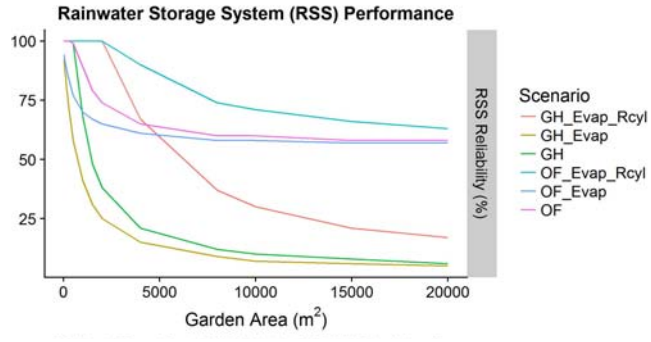

Fig. 3. performance results for garden - larger areas

In reality the crop yields are highly dependent on a number of factors including proper farm management, pest control, etc. Other unforseen issues can also present many problems, as for example in the first year of the reservoir the poor quality PCV used to seal the reservoir developed holes and leaked and was unusable. Currently pest control is an issue, and financial considerations are often prevalent. However, the simulation results do indicate that from a water perspective at least, there is considerable potential to increase vegetable production and meet nutritional needs (vegetable) at the orphanage. Alternatively high value crops could be sold and needed vegetables bought at the market. A combination may be the best option where some crops are sold while others are used directly. Education in agricultural and water resources management and possibly agricultural market economics will be essential for successful project implementation.

Engineering education needs to include a multidisciplinary approach and build stronger relationships to other disciplines, particularly the social sciences and education sectors, but also agriculture. Increasingly it is found that engineering projects are more successful when they take a human centred design approach as promoted by Engineers Without Borders (EWB) Australia, who actively support such improvements to engineering curricula [28].

IV. Conclusion

Rainwater harvesting use in urban agriculture shows great promise in supporting food production and increasing nutrition in developing countries. This is particularly relevant in areas that do not have access to mains water supply and have an arid or semi-arid climate or long dry periods. In this paper we have shown that an orphanage supporting up to 45 adults and 120 children could potentially grow all its own vegetables needs.

The existing system of 1000 kL open reservoir, 1400 m^2 roof and 8 kL/day recycled water inflow could fully support up to 2000 m^2 of greenhouses or open field. Expense may well be a hindrance to expanding the greenhouse area so much. Proper water management and seasonally appropriate plantings may well mean that larger open field areas can be supported.

The amount of land that can be supported can theoretically yield 14530kg of vegetables per year, almost fully supplying the orphanage with the WHO recommended amount of fruit and vegetables per person (total of 14600kg/year), high value vegetables could be sold or exchanged.

Further research should focus on methods for increasing the potential land area that can be supported, the appropriateness and analysis of various greenhouse types, shade nets or open field household agriculture, contingencies for dry years, and the social and economic aspects of implementations. A community educational program is deemed as an essential part for maximizing water use efficiency, nutritional value of the food produced for consumption and the economic value of the food intended for sale. Successful solutions are expected to be the result of a multi-disciplinary effort. Finally, a trial program should be conducted to assess the feasibility and potential problems.

V. Acknowledgment

We would like to thank Peder Pedersen of The Charitable Foundation (TCF) (www.thecharitablefoundation.org) for putting me in touch with Sotheycan (www.sotheycan.org). We would also like to thank Cassandra Treadwell, Keri Chittenden and particularly James Wabara for answering my many pestering questions about the physical layout of the Miti Mingi Villlage, Nakuru Kenya. Authors would like to acknowledge the NASA Langley Research Center POWER Project funded through the NASA Earth Science Directorate Applied Science Program for providing the climate data.

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Study on Steel-Concrete Composite Structure Incorporating BubbleDeck Slab

Rahul Varma
School of Computing Engineering & Mathematics
Western Sydney University
Kingswood, NSW, Australia
18625211@student.westernsydney.edu.au

Ee Loon Tan
School of Computing Engineering & Mathematics
Western Sydney University
Kingswood, NSW, Australia
e.tan@westernsydney.edu.au

Balbir Singh
School of Computing Engineering & Mathematics
Western Sydney University
Kingswood, NSW, Australia
Balbir.singh@westernsydney.edu.au

***Abstract*— Composite steel-concrete structure is an innovative technique to connect steel and concrete using shear connectors. Since the development in civil engineering, the use of conventional concrete has attracted some of the major problems in civil infrastructures such as dead loads, flexibility, slower construction and environmental concerns such as release of greenhouse gases during the production. BubbleDeck system, a new frontier in the civil structures involves recycled high density polyethylene hollow spheres, has enabled engineers to replace the concrete in the middle section of the slab where it has no structural function, thus decreasing the dead load and improving structural integrity. These biaxial slabs have many advantages over conventional slabs: green technology, increased slab span between the columns, lesser material use and easier transportation hence reducing cost of construction. The purpose of this paper is to determine the advantages of BubbleDeck system over the conventional concrete used in slabs. Specific objectives are to investigate the results produced from push-out test using different samples for fatigue strength of shear connectors and strength capacity of BubbleDeck slab. Experimental results concluded that shear capacity of BubbleDeck slab in composite structure is 5-10% less than its Control solid slab. The observations showed that pull-out in BubbleDeck slab is minor as only 1 pull-out occurred out of 16 specimens tested and that may be due to excessive air voids near shear studs. The proximity of shear connectors to voids does not have significant effect on the capacity of the stud, with respect to the designs tested. It is hoped that this study will help future researches to test designs at larger scale and the load per slip data of each test can be compared to determine the most efficient construction method for specific project.**

Keywords*— *BubbleDeck Slab, Steel-Concrete Composite slab, Push-out test, Shear studs.

I. INTRODUCTION

A concrete slab is an integral member and one of the largest consumers of concrete in the modern-day buildings. Concrete, a quasi-brittle material, having high compressive strength and significantly low tensile strength has cement as the main ingredient. Construction of concrete members has a severe impact on environment as the production of cement releases up to 5 to 10% of global CO2, therefore it must be optimized [1]. Common designs include live and dead loads coming on the slab and transferred to the columns through beams. Consequently, slab weight must be reduced to lessen the load on columns using Bubble deck System.

By 1950, development of shear connectors or shear studs had enabled the engineers to connect the concrete slab to steel beams. A composite structure consists a shear connector, which are welded on the flange of a steel beam, over which reinforced concrete slab is casted to support the slab. This idea boosted the growth of high-rise civil structures by reducing the cost and load acting on the columns.

Jorgen Breuning, a Danish engineer invented BubbleDeck, which involves high density recycled hollow plastic spheres known as bubble that are placed in the lattice of steel reinforcement. From figure 1, biaxial hollow-core slab virtually eliminates all concrete from the middle of a floor where concrete has no structural function. Thus, resulting in lighter slab by 35% compared to solid slab with same bearing capacity [2].

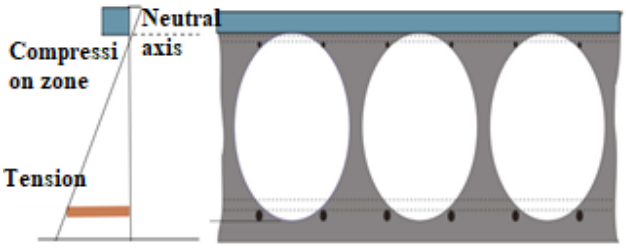

Fig. 1. Cross sectional and stress diagram of BubbleDeck slab [3].

II. EXPERIMENTAL INVESTIGATION

A. Premise

A total of 16 specimens are casted with varying dimensions. 6 Specimens tested in the year 2016 are quoted as “Experiment 1” and 10 specimens tested in the year 2019 are quoted as “Experiment 2”. Dimensions and other physical attributes of each specimens are mentioned in this chapter.

B. Push-Out Test

A total of 16 specimen are casted as the push-out test specimen that consist of a short piece of I-steel beam that is connected on both sides to concrete slabs by means of shear connectors. The slab are bedded down on mortar directly onto the reaction floor with point load being applied to the upper end of the member. Average horizontal and vertical slip (mm) between the slabs and the steel is measured and drawn on the graph against the average loading (kN).

C. Shear Connectors

The purpose of the push-out test is to test the shear capacity of the shear studs welded on the steel beam. From Eurocode 4, pairs of the shear connectors must be minimum 100mm apart to take the head of studs into account. This project chose 19mm end welded headed shear studs at 100mm and 150mm lengths. These studs will make either 2 rows or 3 rows that is total of 4 or 6 number of studs in the whole system depending on the system design. As per the AS2327.1, where the diameter of the studs is an approved size as well as the height. It suggests that for the design to be safe, the height of the studs must be four times of its diameter.

D. Reinforcement

BubbleDeck system requires top and bottom reinforcement for two reasons; first, to provide tensional strength across the specimen since the concrete is vulnerable under both compression and tension forces. Secondly, reinforcement is used to hold the bubbles in place, so it doesn't move while pouring the concrete. Since there is no guide available by the Eurocode or the BubbleDeck company on reinforcement, Experiment 1 use N12 steel bars for top and bottom mesh and Experiment 2 use N8 and N10 steel bars for top and bottom mesh respectively as show in the figure 2.

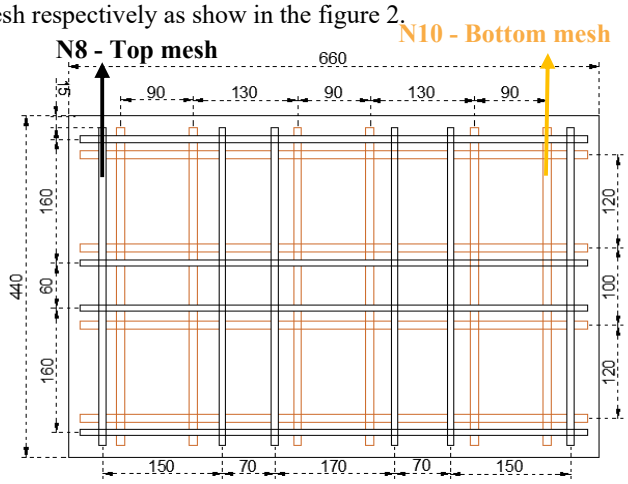

Fig. 2. Reinforcement details of experiment 2.

E. Dimensions

Experiment 1 consisted 6 specimens whereas experiment 2 consisted 10 specimens. These dimensions varied in slab width, stud size and their locations as well as the location of the bubbles in the slab to provide varying results for comparison and recommendations. Common material properties between both experiments are mentioned in table 1.

TABLE I. COMMON MATERIAL PROPERTIES.

Material	Strength
Concrete (15mm cover)	32MPa
Steel Reinforcement	450 < fsy < 550 MPa
Steel beam	250UC89
Steel Section	300MPa

1) Experiment 1 details: The slab dimension for Experiment 1 is 660 x 660 x 230 mm.

TABLE II. EXPERIMENT 1 SPECIFICATIONS.

Label	Type	Spacing b/w bubbles	Total no. of studs
C2150-00	Control	n/a	4
C4150-00	Control	n/a	8
B2150-440	BubbleDeck	440mm	4
B4150-440	BubbleDeck	440mm	8
B2150-220	BubbleDeck	220mm	4
B4150-220	BubbleDeck	220mm	8

Table II depicts experiment 1 detailed specifications. Shear studs used are 19mm x 150mm for each experiment whereas steel reinforcement is N12 for both top and bottom mesh.

Terminology is done in such a way that it describes the specification of the specimen. For example, C and B in table II is abbreviated for "Control" and "BubbleDeck" respectively. Following 2 and 4 is the number of studs used. Moreover, following 150 is the length of the shear connector. And finally, 220 and 440 is the spacing between the bubbles. Fig. 3 and Fig. 4 represents C2150-000 and B4150-440 respectively for visual understanding of experiment 1. All design specifications remain consistent except location and number of studs and location of bubbles which are mentioned in table II.

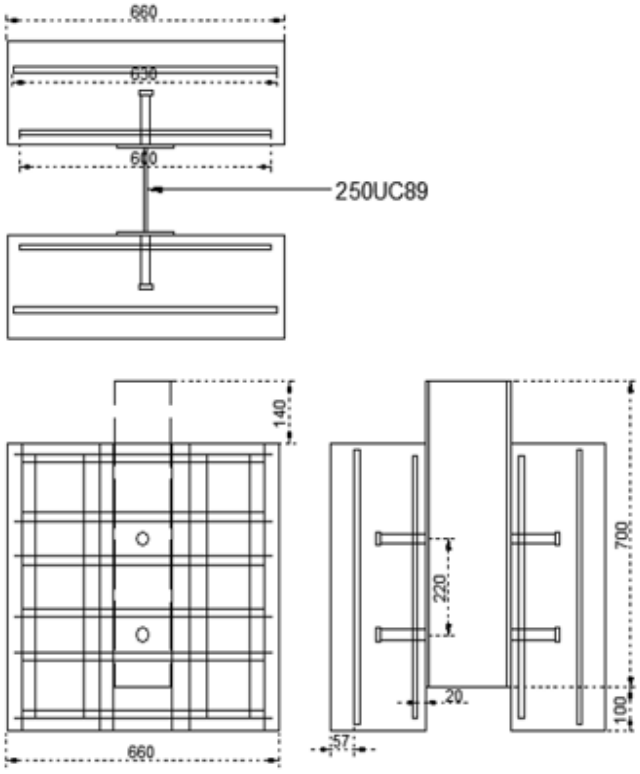

Fig. 3. C2150-000 Specification – experiment 1.

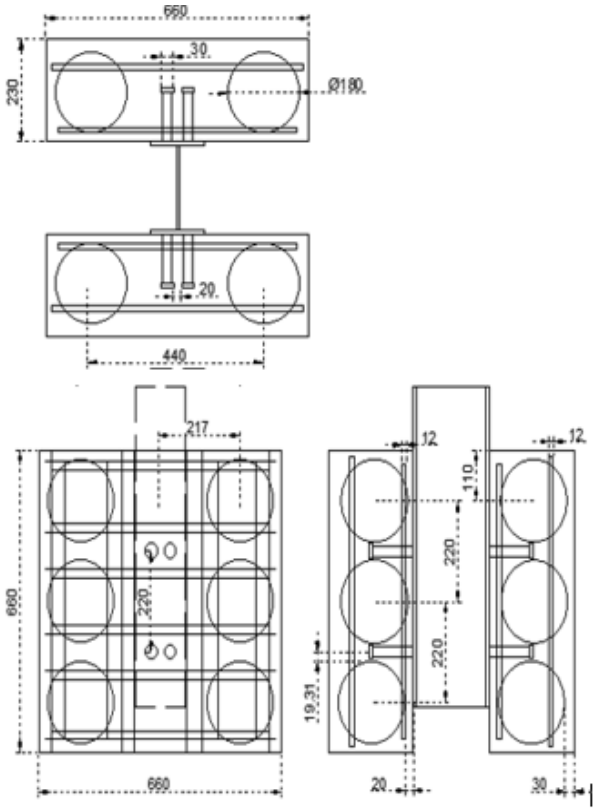

Fig. 4. B4150-440 Specification – experiment 1.

2) Experiment 2 details: 2019 experiment i.e. experiment 2 which involved 10 different design specifications. Control Composite (solid), BubbleDeck and Precast BubbleDeck slabs are under investigation so that the results from push-out test can be compared to experiment 1 to recommend the best designs in terms of placement of bubbles and location of the shear studs.

The composite structure for "Experiment 2" has the dimension of 660 x 440 x 230 mm with steel beam 250UC89. Top and bottom steel bar reinforcement is N8 and N10 respectively. Shear studs are 19mm x (100,150mm). Detailed specification of specimens are mentioned in table III below and nomenclature is similar to experiment 1.

TABLE III. EXPERIMENT 2 SPECIFICATIONS.

Label	Type	Shear Studs	No. of stud row	Total no. of studs
C2100	Control	19mm x 100mm	2	4
B2100	BubbleDeck	19mm x 100mm	2	4
P2100	Precast	19mm x 100mm	2	4
C2150	Control	19mm x 150mm	2	4
B2150	BubbleDeck	19mm x 150mm	2	4
P2150	Precast	19mm x 150mm	2	4
C3100	Control	19mm x 100mm	3	8
B3100	BubbleDeck	19mm x 100mm	3	8
C3150	Control	19mm x 150mm	3	8
B3150	BubbleDeck	19mm x 150mm	3	8

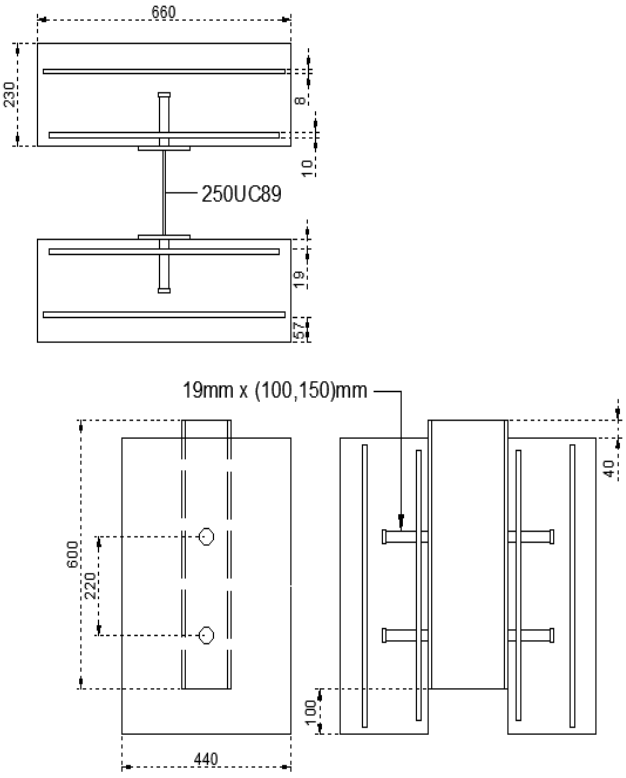

Fig. 5. Control C2100, C2150 Specification – experiment 2.

As can be seen from figure 5, slab width and beam length has been reduced to propose best design approach.

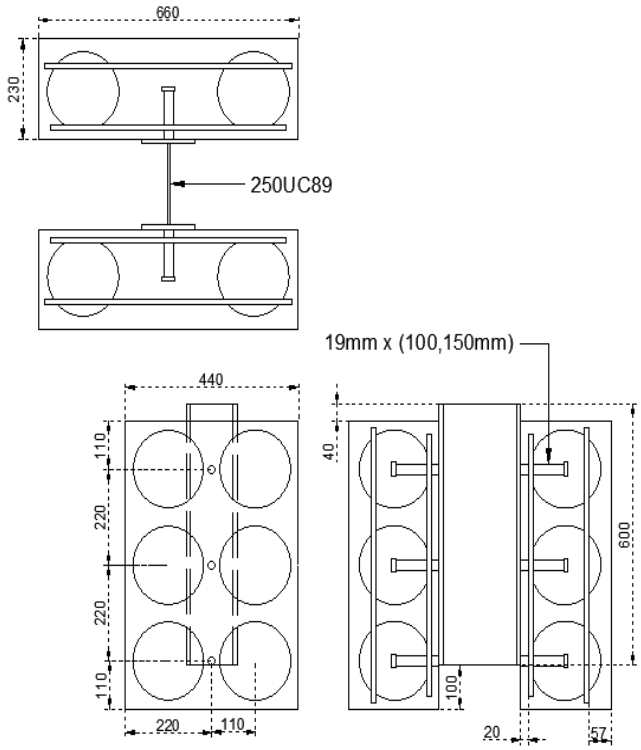

Fig. 6. B3100 & B3150 Specification – experiment 2.

Figure 6 shows three rows of studs are used at 220mm spacing between them and 110mm spacing from the edge of the slab.

III. Results and Discussions.

All 16 specimens were casted and subjected to push-out test where vertical displacement by the beam, stud yield points, maximum loading and failure modes can be analyzed. Following figure 7 to figure 22 are results obtained from the push-out test which depicts the average vertical slip vs the load experienced by each stud.

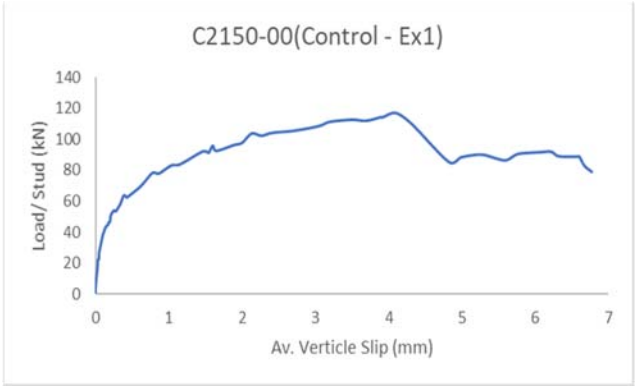

Fig. 7. C2150-00 push-out test result

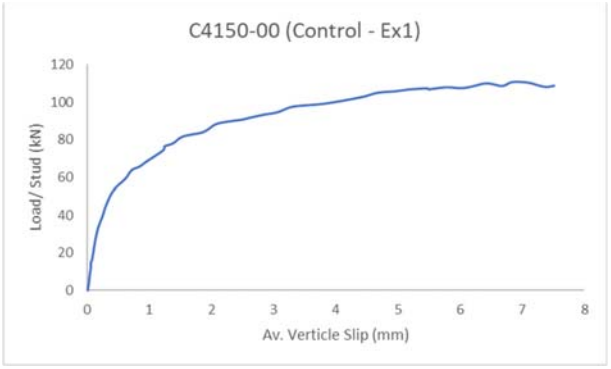

Fig. 8. C4150-00 Push-out result.

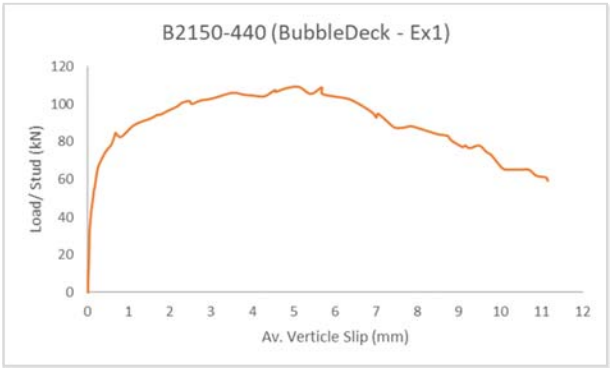

Fig. 9. B2150-440 push-out test result.

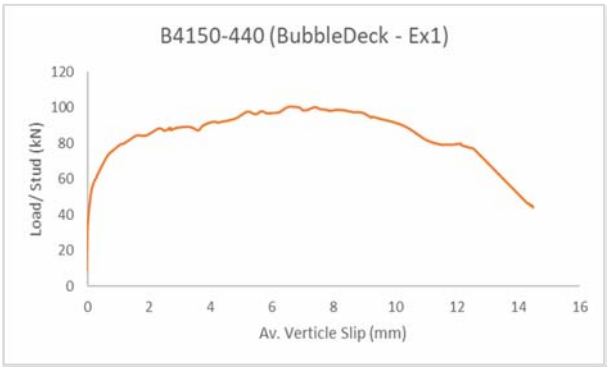

Fig. 10. B4150-440 push-out test result.

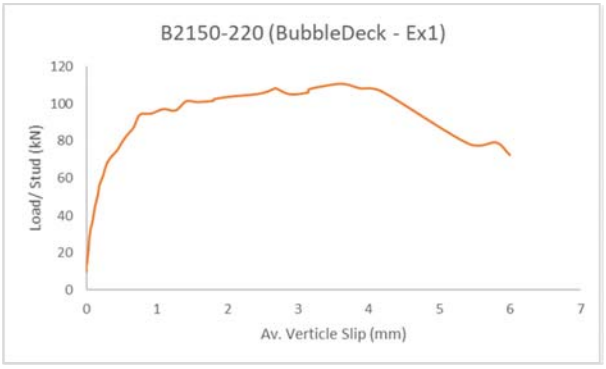

Fig. 11. B2150-220 push-out result.

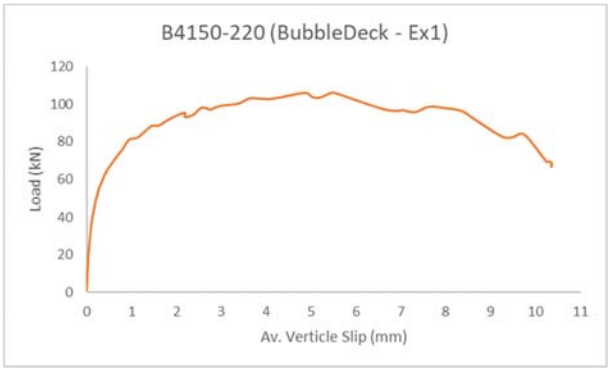

Fig. 12. B4150-220 push-out result.

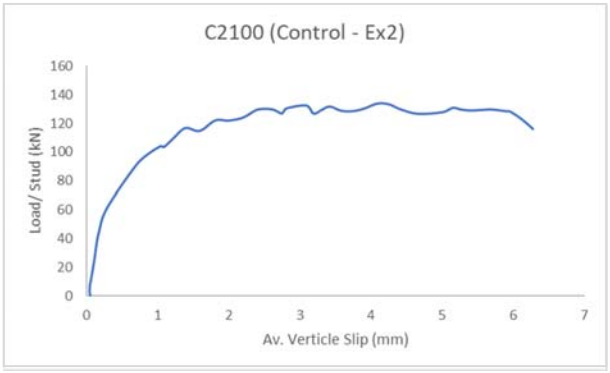

Fig. 13. C2100 push-out result.

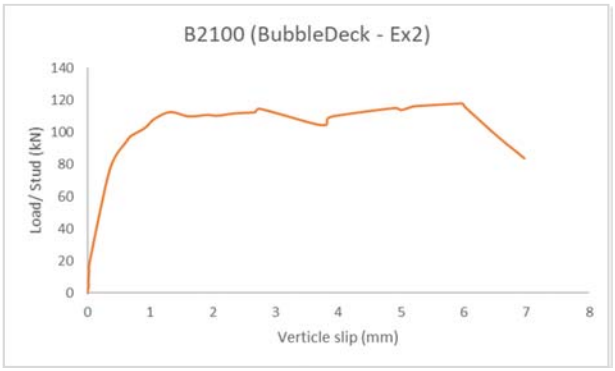

Fig. 14. B2100 push-out result.

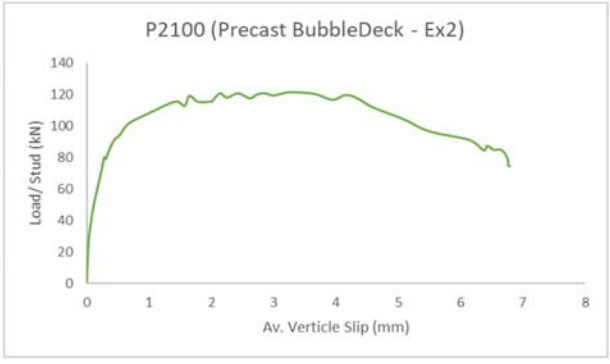

Fig. 15. P2100 push-out result.

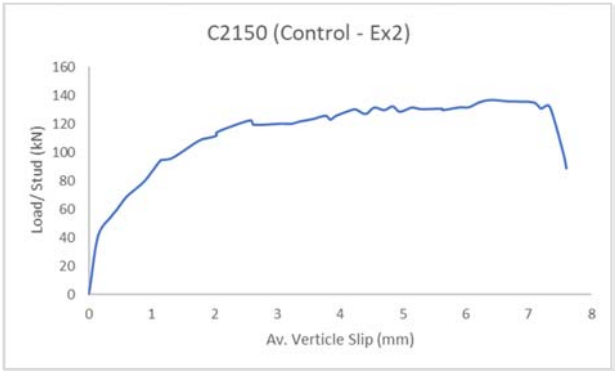

Fig. 16. C2150 push-out result.

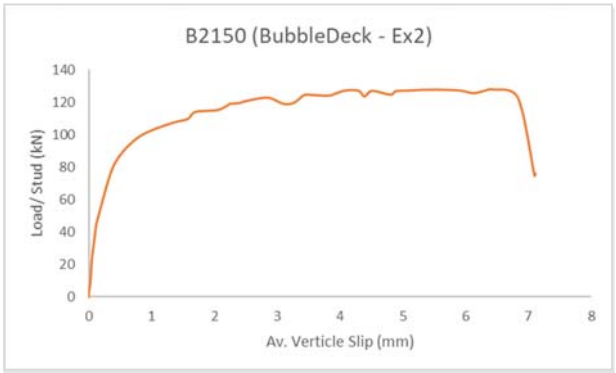

Fig. 17. B2150 push-out test result.

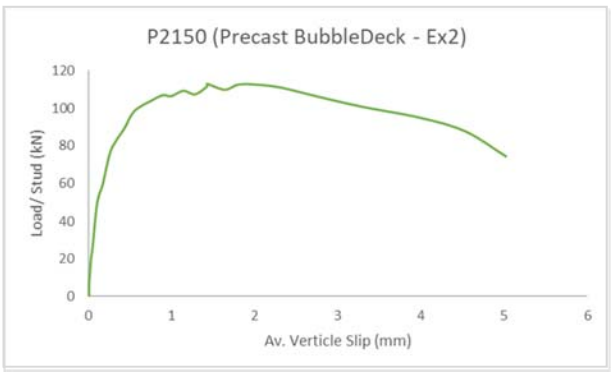

Fig. 18. P2150 push-test result.

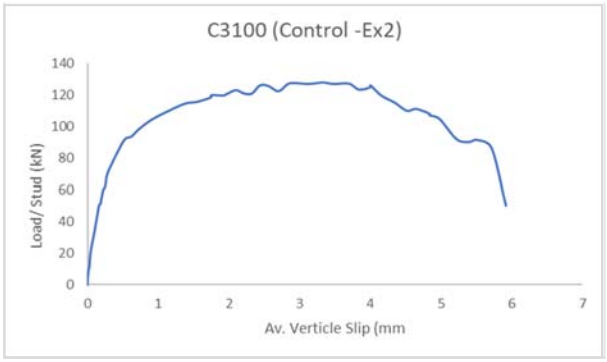

Fig. 19. C3100 push-out test result.

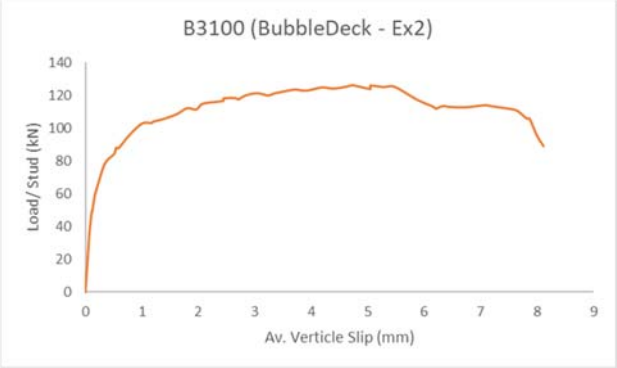

Fig. 20. B3100 push-out test result.

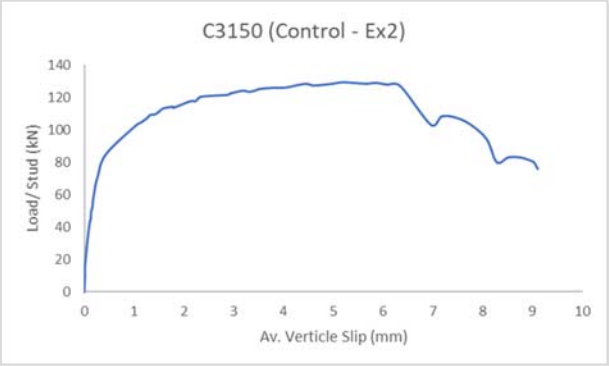

Fig. 21. C3150 push-out test result.

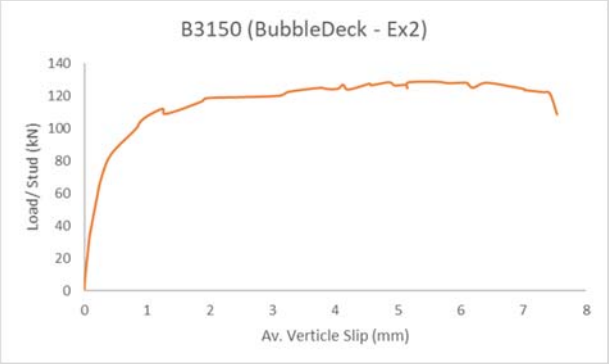

Fig. 22. B3150 push-out test result.

A. *Loading per Studs.*

Discounting the results from B4150-400 where the failure occurred due to beam pull-out, there was a marginal difference of about 10-18% in the load suffered by each stud. Above results are average of 4 or 6 LPs which are located at each stud depending on specimens' specification. Therefore, these results indicate that the stud welds were uniform and were undergone in similar test conditions. Similarly, Experiment 2 dealt with 10 specimens, each categorized according to the number of studs used and their length. Findings from experiment 1 found that bubbles spaced at 440mm had lower strength capacity than placed at 220mm as can be seen in table 6. To assess this problem in detail, findings from experiment 1 was utilized in experiment 2. The purpose of this set of experiment was to attain variety for trial and error. Slab width was reduced to 440mm and bubbles were spaced at 435mm on the length side as mentioned in previous chapters. In this study, precast BubbleDeck slab was added to then compare with solid slab and conventional BubbleDeck slab system.

In experiment 1, C2150-000 achieved the highest loading per stud at 117kN, which is just above the pre-test expectation of 115kN and B4150-220 achieved the lowest at 100.2kN for which no previous data was available to compare. This variance in result suggests that with only one row of stud could distribute the entire load consumed to the full failure cone of concrete, wherein 2 rows (4150s) of stud had overlapping concrete cones resulting in higher overall shear strength. Therefore, in experiment 2, one row of studs was utilized, and it was found that C2100 achieved the highest loading per stud at 134.53kN, which is also above the pre-test expectation of 115kN and P2150 achieved the lowest at 114.8 kN. Despite, P2150 achieving lowest stud capacity, it is far larger strength than 90kN recommended by Eurocode.

Furthermore, in experiment 2, there was only 5-8% of reduction in average load carried by studs when compared between BubbleDeck system and their respective conventional control slab. This stands a concrete proof in achieving almost similar strength to the conventional composite slabs. Precast slabs namely P2100 and P2150 are also compared with each other to check the effects of length of shear studs. It is noticed that P2100 and P2150 using 2 studs of 100mm and 150mm length respectively, had about 6% reduction in load per stud capacity. 100mm achieving higher strength. Both specimens began developing minor cracking around the stud region during yielding hence, both samples had stud failure as the outcome. The effect of the length is uncertain at the moment but perhaps it is how precast reacts. Contrary, BubbleDeck increased its yielding capacity when length of the stud was increased. However, this increment was marginal.

TABLE IV. AVERAGE LOADING PER STUD COMPARISION.

Experiment 1			**Experiment 2**		
Specimen no.	**Av. Load per stud (kN)**	**% difference**	**Specimen no.**	**Av. Load per stud (kN)**	**% difference**
C2150-000	117	0%	**C2100**	134.53	0%
B2150-220	109.11	-5.7%	**B2100**	118.05	-14%
B2150-440	110.7	-7.2%	**P2100**	121.8	-10.45%
C4150-000	110.44	0%	**C2150**	136.60	0%
B4150-220	105.78	-4%	**B2150**	129.44	-5.5%

B4150-440	100.2	-10.2%	**P2150**	114.8	-18.7%
			C3100	119.75	0%
			B3100	127.76	6.3%
			C3150	130.035	0%
			B3150	125.96	-3.23%

B. Failure Mode

Stud failure was common in almost all the specimens. Each specimen gave early signs of being cracked near the studs. However, an abnormality was found while testing B4150-220 and C3150.

B4150-220 was the only specimen where pull-out was an issue which resulted in the lowest stud capacity out of all. This occurred because concrete failed before the stud reached its maximum capacity. Nevertheless, 100.2kN is still above standard capacity of 90kN for any stud in any system.

Fig. 23. B4150-440 concrete pull-out [4].

As of now, it is unclear about why pull-out failure occurred in this specimen and not in B4150-220 where the only difference was in spacing of the bubbles. However, upon closer look at the results and figure 7 for B4150-440, it is noticed that the loading increased up until 85kN where stud began to yield slowly. During that time, vertical slip rapidly increases, suggesting a concrete failure as deep cracks began to form. From figure 7, it is noticed that beam separation is invalid as beam is completely intact with the studs and deep cracks are formed around the stud until the concrete is failed. Due to uncertainty about the cause of pull-out only assumptions can be made to progress the theory. There are several reasons why this could have happened. Perhaps, poor compaction or vibration while casting led to develop air voids around the shear stud which resulted in weak concrete around the stud that experienced the concrete pull-out. Such an inclusion in the cone-failure zone could have caused a premature failure in the specimen [4].

During the early stages of testing, C3150 did not show any physical stress or cracks, rather it showed fluctuations on the software recording push-out test data. The load was increased and then hit the plateau and drop to rise again and interestingly, C3150 achieved the highest overall loading of 780.21kN. Once the mark was reached, there was a sudden bang noise and the steel beam was completely separated from the concrete.

Similarly, beam separation due to stud failure in experiment 1 was also noticed in B2150-440 as shown in figure 8 below.

Fig. 24. Complete beam separation due to stud failure I B2150-440.

As for the stud failure is concerned, all solid slabs except C3150 in experiment 2, reached the highest capacity than where the BubbleDeck was utilized. This was expected from the literature review because solid slabs have higher structural stiffness and lower vertical slips. Upon post-test analysis of the specimen, as seen from figure 58, it was concluded that all the studs had yielded and snapped through the shaft. Furthermore, the surface of the failed stud seems flat suggesting the stud snapped completely under excessive load. Additionally, analysis disclosed that weld failure could be disregarded as this was not the case, else the results would be worthless.

(i) (ii) (iii)

Fig. 25. Stud failure in (i)- B2150-000, (ii)- C2150-000 and (iii)- P2150.

C. Cracking Pattern.

A comparison between experiment 1 and experiment 2 on cracking pattern cannot be drawn since both experiments showed different patterns in the results.

In experiment 1, minor and deep inclined shear cracking was found in all the specimens except solid (Control) slabs because structural stiffness being higher in control slabs shown in table V. These cracks can occur due to excessive displacement both vertical and horizontal due to stud yield or it may have formed due to concrete failure. As per the results found, cracks developed due to excessive displacement of the beam and studs in both directions except in the specimen B4150-440 where concrete must have failed for pull-out situation.

TABLE V. EXPERIMENT 1 CRACKING PATTERN.

Label	Crack Pattern
C2150-000	No cracking
B2150-220	Minor cracking
B2150-440	Minor cracking
C4150-000	No cracking
B4150-220	Minor cracking
B4150-440	Deep cracking

However, in experiment 2, random patterns in results were found mentioned in table VI. For example, in C2100 and C3100, deep cracks were present whereas in C2150 and C3150 minor or no cracking was found. Similarly, in P2100 there was no cracking and in P2150 deep cracking was found. This randomness can be assumed to be the result of either improper concrete vibration when casting or major variance in loading stroke applied by the push-out machine as observed from their respective graphs.

Hence, this suggests that the limit between shear failure and concrete failure in BubbleDeck specimen is relatively close.

TABLE VI. EXPERIMENT 2 CRACKING PATTERN.

Label	Crack Pattern
C2100	Deep shear cracks
B2100	Inclined shear cracks
P2100	No cracking
C2150	Inclined shear cracks
B2150	Inclined shear cracks
P2150	Deep shear cracks
C3100	Deep shear cracks
B3100	Inclined shear cracks
C3150	No cracking
B3150	N/a (Beam separation)

D. Average Maximum Load.

Figure 10 depicts average maximum loads in BubbleDeck configuration, which suggests that in experiment 1 approximately 6% of load is lower than the solid slab where only a single row of stud is used. Whereas, there is only 4% reduction in loading is experienced by B4150-220 when compared to its control opponent i.e. C4150-000. And in experiment 2, there is only 3-5% drop in BubbleDeck when compared to its control counterpart.

However, approximately 13% reduction in of maximum load in B2100 fails to impress the design specification when compared with C2100. Effects of the location and quantity of the studs and bubbles can also be noticed from figure 10, which concludes that when only 2 studs are used, the load capacity is approximately half than when 4 studs are used in experiment 1. Furthermore, the capacity is increased when the number of studs are increased. For example, there is an increase of 62% in maximum load carrying capacity between B2100 where 2 studs are used and B3100 where 3 studs are used each 100mm in length.

Fig. 26. Average Maximum Load.

Moreover, the spacing of the bubbles plays an important role in the BubbleDeck system as it can be noticed that when bubbles are placed 220mm apart gives more strength than when bubbles are placed 440mm. this is due to the higher structural stiffness.

Eurocode suggests that for a worthy result to be accounted, a minimum of three identical tests must be performed with similar results. However, this experimental program does not have the time nor the funding available to test such a sample size, hence the results obtain from this study serve merely an inspiration for future research.

E. Vertical Slip.

As for the vertical slip is concerned, All the specimens showed both key similarities and differences. Graphs presented in results shows a similar curve to the Eurocode in the loading phase. Linear progression of vertical slip is observed before and during the stud yields. However, sharp drops loading is observed when the stud completely fails hence, the test is stopped. These points are characterised by sudden load decrease and vertical displacement increase.

TABLE VII. VERTICAL SLIP COMPARISION.

Label	Ultimate Vertical Slip (mm)	Label	Ultimate Vertical Slip (mm)
C2150-000	6.7	C2100	6.27
B2150-220	6.01	B2100	6.98
B2150-440	11.1	P2100	6.78
C4150-000	7.5	C2150	7.59
B4150-220	10.36	B2150	7.09
B4150-440	14.49	P2150	5.04
		C3100	5.91
		B3100	8.11
		C3150	9.01
		B3150	7.54

The variation in the location of bubbles and studs were included in each specimen as well as the precast concrete was used in 2 sets of design to study the proximity. Results measured in table VII may have not reflected the results expected prior to the testing as the objective was to gain more strength with minimum vertical slip than its control specimen. Initially, it was theorized that proximity of studs to voids would result in premature failure of the specimen i.e. minimum load per stud with large vertical slip. However, this was only true for B4150-440 where the distance between the studs and the bubbles was the largest since the stud started to yield at 67.25kN, much earlier than rest of the specimens.

IV. CONCLUSIONS AND RECOMMENDATIONS

The ability of BubbleDeck slab when comparing with conventional composite slab remains almost similar. Advantages of BubbleDeck System are far more beneficial than conventional concrete. It is faster to construct, weighs dramatically less up to 25%, can be easily precasted and transported to the site. The main aim of this part of thesis was to compare and determine load/stud, failure mode, ultimate vertical slip and crack pattern using push-out tests. Through proper research and planning, following conclusions can be made.

This study shows that the pull-out is a minor concern in BubbleDeck as only 1 specimen experienced pull-out out of 16 specimens. In experiment 1 approximately 6% of load is lower than the solid slab where only a single row of stud is used. Whereas, there is only 4% reduction in loading is experienced by B4150-220 when compared to its control opponent i.e. C4150-000. And in experiment 2, there is only 3-5% drop in BubbleDeck when compared to its control counterpart. This suggests that BubbleDeck can be designed using traditional means of calculation and applying capacity reduction factor to the capacity of shear studs.

One stud per row gives more strength per stud than 2 studs in a row due to overlapping concrete cones resulting in higher overall shear strength.

Increased number for studs in the system gives more ultimate load capacity by at least 50%. For example, (C, B)4150s in experiment 1 and (C, B)3100s and (C, B)3150s in experiment 2. However, system with 3 or 4 studs experienced larger values of vertical slip.

Bubbles closer to the studs gives less load/ stud value due to structural stiffness and overlapping concrete cones of studs. Nevertheless, this decrement is only 1.45% when noticed in B2150-220 (109.11kN) and B2150-440(110.7kN). Furthermore, when slab width is decreased from 660mm to 440mm and c/c distance between bubbles from 440mm to 435, resulted in increase in strength by over 17%.

Precast specimens P2100 and P2150 achieved the least maximum load due to space between aggregate was one of the issues for lower strength and hence it is recommended to use proper vibration method in the future to test precast more efficiently.

Therefore, due to marginal strength difference in BubbleDeck than Soli slab, it is fair to conclude that BubbleDeck is a better alternative to solid slab when the requirement is lighter and faster construction, flexibility in shape and when environmental concerns are accounted. Furthermore, it is far superior in strength and reliability than hollow core slab and VCS. Since, the primary objective of this thesis is served, it is recommended that future studies involve larger size specimen for more detailed results of real-life situations. It is recommended that more tests must be carried out in a similar fashion using different stud arrangement and the diameter of bubbles.

The load per slip data of each test can be compared to determine the most efficient construction method for specific project.

ACKNOWLEDGMENT

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Also, we extend our gratitude to One Steel for arranging N8 reo bars in very short notice.

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Implementation of Embedded Work Integrated Learning in Mechanical Engineering Courses at Western Sydney University

Mariam Darestani
School of Computing, Engineering and Mathematics, Western Sydney University, Penrith, NSW 2751, Australia
M.Darestani@westernsydney.edu.au

Richard (Chunhui) Yang
School of Computing, Engineering and Mathematics, Western Sydney University, Penrith, NSW 2751, Australia
R.Yang@westernsydney.edu.au

***Abstract*—This exploratory study seeks to prompt discussions about strategic decision-making surrounding the implementation of Work Integrated Learning (WIL) in mechanical engineering education at Western Sydney University (WSU). The aim of engineering curriculum at WSU is to graduate students with competencies required for an engineer in Australia. The program is also aspiring to develop graduate knowledge, skills and capabilities known to be in high demand for success in the future of work and society. In present study, effective WIL programs in engineering and STEM in Australian context are reviewed. Practical limitations and challenges of implementation of WIL at WSU are identified by conducting interviews with different stakeholders. This investigation suggests that embedding WIL activities in teaching from first year is more effective that limiting WIL to industry placement in the third or fourth year. This study also suggests that including activities such as projects in collaborations with industrial partners in mocked work environment and entrepreneurship training in engineering curricula could have higher impacts in achieving learning outcomes of the courses compare to more common practices, such as field trip and guest speakers. Units with WIL elements in mechanical engineering are further identified, evaluated and trial plan are made to improve the embedded WIL in mechanical engineering discipline.**

Keywords—Mechanical engineering education; professional education; Work-Integrated Learning (WIL); Embedded Work Integrated Learning (EWIL), Work placement

I. INTRODUCTION

Work Integrated Learning (WIL) is widely implemented as an effective pedagogical strategy [1-2] and a quality learning experience which enhances students' employability[3]. Graduating students that are equipped with knowledge, skills and capabilities required to meet expectations of employers is of immense importance for the productivity of workforce [3]. Pedagogically, WIL is "a practice whereby students come to learn from the integration of experiences in educational and workplace settings" [4]. The definition developed for WIL by universities is very similar across Australia in spite of different terminologies used. Commonly-used definition is integrating theory with the practice of work and engagement with the industry and community [5-7]. Regardless of its definitions, an effective WIL program should be able to merges practice and theory for students and clearly link to theoretical aspects of the course. It has strong engagements with industry or community; and has clear targets and expectations of both students and industrial partners [8].

The aim of this study is to review WIL practices in engineering field in Australia and in particular, identify opportunities and challenges of further implementing a WIL strategy in mechanical engineering teaching. Fulfilling Engineering Australia competencies criteria is one of main targets and in line with WSU policies and we devise the innovative strategy to fulfil specific learning outcomes and also 21st century course design elements.

II. OPPORTUNITIES AND CHALLENGES FOR WIL IN AUSTRALIA

A well designed WIL program offers numerous benefits to different stakeholders: students, industry and community partners, higher education institutions, governments, etc.. However, in comparison with traditional classroom-based teaching, novel strategies are required to integrate theory with practice. University educators must recognise that the benefits of work-integrated learning are not implicit within the work itself and it is important that WIL is structured purposefully and grounded in learning theories [9]. A review of WIL programs in STEM in Australian Universities concluded that a WIL program should have the support of leadership and dedication of academics to succeed. Difficulties in attracting enough employers to participate in WIL activities, under resourcing WIL program and in general lack of value places on WIL were identified as the main challenges of a implementing WIL in engineering and STEM in Australia[8]. Latest report on WIL in Australia [10] identified that varied understandings of WIL across education industry in Australia is still a problem and further work is required to categories WIL activities. Another interesting finding is that students valued WIL experiences regardless of their credit gaining potentials. However, it was also found that international students and equity groups across different disciplines faced practical limitation in accessing WIL experiences.

WIL programs in most Australian engineering schools are implemented by mainly focusing on industry placement and explicitly presented in a unit with zero credit point but compulsory to finish in the third or fourth year for a typical 4-year Bachelor of Engineering Honours program. However, strategic placement of work experiences should be implemented throughout the curriculum, which is classified and known as Embedded Work Integrated Learning (EWIL) is much effective. In this method, the work placements and other WIL activities are purposefully woven or embedded into subjects throughout the degree The most important factors in designing a quality EWIL curriculum are: 1) EWIL elements must align with learning outcomes, 2) planned strategically; and 3) prepared well, evaluated and reviewed [11-13].

III. SIGNIFICANCE OF WIL AT WESTERN SYDNEY UNIVERSITY

In 2017, WSU blueprint nominated the work-integrated learning and related concepts as components of a student-centred university with regional, national and global impacts and guarantees the student a research-informed learning experience as an anchor institution [14]. Specific goals addressed by the work-integrated learning include: strengthening career preparedness and employability (1.4); building research-informed networks by engaging and partnering with industry, business, government and community (2.2); preparing students for the complex world of work and further contribution to the community (3.11); and programmes meeting the needs of regional employers (5.10). Industry engagement also provides academics with opportunities for driving a culture of co-creation of research with WSU partners (2.3) and working with government, industry and community partners to advocate on issues that harness opportunities for Greater Western Sydney (5.10).

These new WSU teaching and learning guidelines recently directed the WSU School of Computing, Engineering and Mathematics (SCEM) to develop a high-level WIL Framework in 2016. The new SCEM WIL Framework provided an information package for WIL to guide the curriculum renewal of undergraduate engineering courses. This curriculum renewal was funded by WSU via a 21C Curriculum Renewal Flagship Project since 2107 to work on six WIL engineering core units across the whole academic years for all levels of undergraduate engineering courses – including 3-year fulltime Bachelor of Engineering Science at Engineering Technologist, 4-year fulltime Bachelor of Engineering (Honours) and Bachelor of Engineering Advanced (Honours), 5-year fulltime Bachelor of Engineering (Honours)/Bachelor of Business at Professional Engineer, etc.

More specifically, WSU in a strategic collaboration with the University of New South Wales, is establishing an innovative engineering course [15]. The aim of the course is to prepare students for their future jobs in changing environment for the 21st century with using the main outcomes of the 21C Curriculum Renewal Project conducted since 2017 [16] and fully taking advantages of strengths from both Western Sydney University and UNSW Sydney to create new opportunities for students. This new program using the EWIL is creating new generations of engineers, who possess social intelligence, technical ability, and creative intelligence required to succeed in meeting future engineering challenges and labour market needs. These targets cannot be achieved only by providing theoretical and conceptual knowledge and innovative teaching approaches should be used to help students practice solving real world problems and team work. Therefore, a well-designed WIL framework is identified as one of the core elements for the WSU Engineering Courses including both existing and new courses.

IV. AN IMPLEMENTATION STRATEGY FOR WIL AT WSU UNDERGRADUATE ENGINEERING COURSES

To design an effective WIL implementation strategy according to the existing WSU SCEM WIL Framework, the embedded WIL approach was fully adopted for undergraduate mechanical engineering courses. In line with well-established Bloom's taxonomy in teaching [17-18], the aim of this EWIL strategy is to prepare students for their future jobs, by helping them move to higher level of thinking by applying the knowledge they gain from lectures, analysing, evaluating and eventually creating. This would be achieved by giving students an opportunity to a) observe, e.g. guest lectures and field trips; b) practice and apply, e.g. by working on projects with real word orientation at simulated work environment; and c) act and plan, e.g. by self-reflecting experience in a real work environment. Therefore, WIL activities in Engineering can be summarised into three categories: 1) learning by observation (field trip and guest lectures), 2) Learning in a simulated work environment in collaboration with industry partner (such as projects with real world orientation at university and entrepreneurship trainings); and 3) Work experience in the industry often supervised by the industry partners.

Both curriculum and extra curriculum activities of engineering programs at WSU are designed to fully fulfil three requirements: a) Course Learning outcomes, b) Engineering Australia competencies [19] as shown in Fig. I; and c) the 21st century Course/Curriculum design elements [16].

In order to identify an effective WIL implementation strategy, potential outcomes of different WIL activities were mapped against the target learning outcomes. As shown in Fig. II, entrepreneurship trainings, followed by projects in the industry, and projects with real world orientation at university completed in collaboration with the industry had highest impact in achieving the learning outcomes. This result is in agreement with the latest applied research into WIL in Australia [20] that suggested universities should consider and implement alternative WIL activities such as: micro-placements, online projects or placements, hackathons/competitions and events, incubators/start-ups and consulting.

It should be pointed out that although this analysis put field visits and guest lectures at the bottom of the list, these activities especially in first and second year are very useful and necessary for students to learn about work of engineers in different industries.

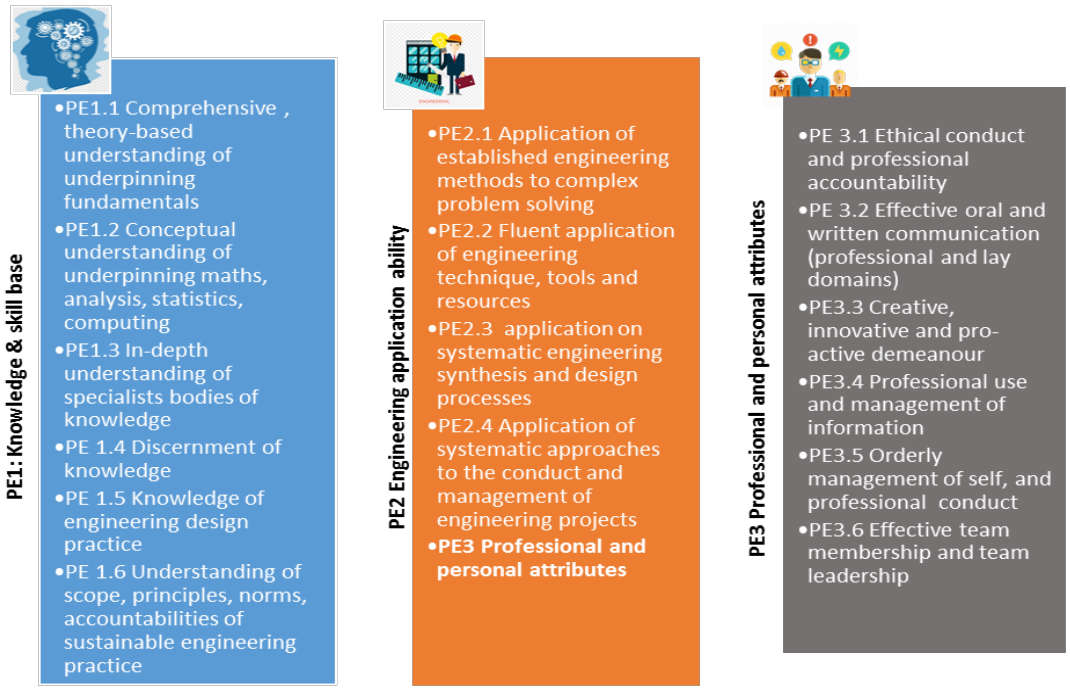

FIG. I. Engineering Australia competencies [19].

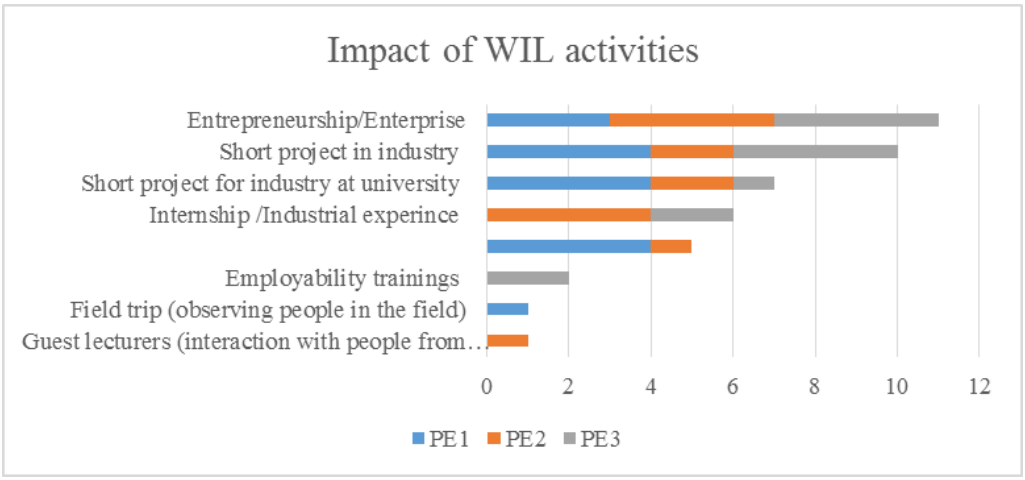

FIG. II. Comparing potential impact of various WIL activities in achieving target learning outcome of Engineering Australia competencies.

V. POTENTIAL CHALLENGES OF WIL IN ENGINEERING AT WSU

To identify main problems of implementation, or in better word expanding WIL activities, interviews were conducted with different stakeholders at WSU. The main problems identified were:

- A lot of current activities can be identified as WIL however; these activities are not coordinated. Often attendance rate is low.
- Guest lectures and field trips are main activities included in lectures. However, a diverse range of activities and higher impact activities are required to achieve learning outcomes
- There is no data or feedback from students to evaluate effectiveness of the current activities. Moreover, there is no mechanism for capturing this activity in student's records.
- Implementation of WIL increases work load for academics and some lectures have not received any training on WIL.

- Most activities are focused on year 3-4 (as industry work placement).
- Moreover, International students struggle to find work placement.

The following solutions were suggested to address above issues:

- Design a centralised WIL platform that is easy to access and navigate, has growing online resources for students and educators, with a mechanism for delivery, evaluation and capturing WIL micro-credentials in student's records.
- Designing an implementation strategy in collaborations with industry and student partners and creating student focused groups for each year, developing a mentoring program and a mechanism for design and delivery in collaboration with industry partners
- Providing training for academics in collaboration with WIL academic leaders in Australia
- Designing a diverse range of WIL activities and trial implementation in small scales.

VI. Embedded WIL elements in mechanical engineering Course at WSU

The undergraduate mechanical engineering courses were offered at their first time in 2011 and they are available across all four degrees – 3-year full-time Bachelor of Engineering Science, 4-year full-time Bachelor of Engineering (Honours) and Bachelor of Engineering Advanced (Honours), and 5-year full-time Bachelor of Engineering (Honours)/Bachelor of Business. The BEng (Hons) and BEngAdv (Hons) degrees were developed to satisfy the Australian Qualifications Framework (AQF) Level 8 requirements, whereas the BEngSc award satisfies the AQF Level 7 requirements. These engineering courses received accreditations from Engineers Australia to achieve Stage 1 Competencies at different levels – BEng (Hons) and BEngAdv (Hons) both at Professional Engineers and BEngSc at Engineering Technologies, respectively.

Both the BEng (Hons) and BEngAdv (Hons) programs are 4-year full-time programs and require a successful completion of 320 Credit Points (32 units at 10 CP each) plus 450 hours (12 weeks at 37.5 hour per week) of industrial experience. Typically, commencing students undertaking these programs enrol during Autumn and Spring semesters as two intakes. Three sub-majors are offered for students – Automation, Biomedical Engineering and Computer Aided Design (Mechanical). A student will need to complete a group of four units (40CP) in a specific area of the chosen key program to gain a sub-major in that area. The Bachelor of Engineering Science is a three-year degree program with the same common first year structure as BEng (Hons) and BEngAdv (Hons) programs. This course also serves as either a pathway to the four-year BEng (Honours) programs or an exit point for students studying BEng (Honours) programs.

In order to fully implement WIL, the curriculum of the WSU Engineering courses has been undergoing continuous development to reinforce the contents, delivery and learning outcomes for WIL, in particular, since 2017. These curriculum developments were performed at both unit and course levels and takes advantage of in-class curricular learning and out-of-class extra-curricular student-centred learning, such as WSU Solar Car Project, SCEM Formula SAE-A Project, SCEM Sustainable House Project, SCEM Robot Challenge Project, which are funded by WSU and SCEM, respectively. WSU Solar Car Project is our extra-curricular student-centred flagship project, which was formally started in 2013 and it will be further described as a case study in next section. These curricular and extra-curricular developments make the WSU mechanical engineering courses having explicit WIL components explicitly.

The challenges in WIL implementation at WSU mentioned-above in Section V are being further sorted out to provide students much better learning experience including both existing and new courses.

Using the four-year degree as an example, BEng (Hons) course has in total 32 units and each unit has 10 credit points (CPs) and 1 zero-CP Work Integrated Learning (WIL) unit and thus a student needs to finish 320 CPs for graduation. Among these 32 units, there are 7 Common Fundamental Units in the first year, 15 Specialisation Core Units, 2 Final Year Project Units, 4 Alternate Units for a sub-major and 4 Elective Units of student choices for Years 3-4. The students are encouraged to use the 4 Elective Unit slots to take a set of four units for the second sub-major or eight units for a second degree, i.e., Bachelor of Applied Leadership and Critical Thinking, Bachelor of Entrepreneurship, Bachelor of Data Science, etc. The curriculum renewal of the WSU undergraduate engineering courses provides flexibility and choices of students as well as options to further enhance the WSU student-centred culture and research-informed learning.

The course structure of BEng (Hons) can be found in Table I, which is the new one as the main outcomes of the 21C Curriculum Renewal Flagship Project in 2018. The EWIL components were implemented from Year 1 to Year 4 by picking up six WIL units, including 300964 Introduction to Engineering Practice (Year 1), 300735 Automated Manufacturing (Year 2), 300487 Mechatronic Design & 300741 Industrial Experience (Engineering) (Year 3), and 301245 Final Year Project 1 & 301246 Final Year Project 2 (Year 4), which are highlighted in this table. All the three categories of WIL activities – learning by observation, learning in a simulated work environment in collaboration with industry partner, leaning by work experience in the industry were well covered in this mechanical engineering course via participating field visits and guest lectures, conducting real-world projects at university, entrepreneurship trainings, etc. These WIL components are being further developed and implemented into the new joint WSU-UNSW BEngAdv (Hons) courses which will be offered in 2021 at the Engineering Innovation Hub, Parramatta City.

Table I Common structure for 3740 BEng(Hons) Course

Yr	Semester	Units			
1st	Autumn	Common Fundamental Unit 1 300743 Mathematics for Engineers Preliminary or 200237 Mathematics for Engineers 1	Common Fundamental Unit 2 300963 Engineering Physics	Common Fundamental Unit 3 300027 Engineering Computing	Common Fundamental Unit 4 300964 Introduction to Engineering Practice
	Spring	Common Fundamental Unit 5 200238 Mathematics for Engineers 2	Common Fundamental Unit 6 300463 Fundamentals of Mechanics	Common Fundamental Unit 7 300965 Engineering Materials	Elective Unit 1
2nd	Autumn	Specialisation Core Unit 1 300035 Kinematics and Kinetics of Machines	Specialisation Core Unit 2 300040 Mechanics of Materials	Specialisation Core Unit 3 300762 Fluid Mechanics	Specialisation Core Unit 4 301076 Graphics 2: Visual Simulation
	Spring	Specialisation Core Unit 5 300480 Dynamics of Mechanical Systems	Specialisation Core Unit 6 300760 Thermodynamics and Heat Transfer	Specialisation Core Unit 7 300761 Advanced Mechanics of Materials	Specialisation Core Unit 8 300735 Automated Manufacturing
3rd	Autumn	Specialisation Core Unit 9 300764 Mechanical Design	Specialisation Core Unit 10 300763 Advanced Dynamics	Elective Unit 2 (Level 2 or higher)	Alternate Unit 1
	Spring	Specialisation Core Unit 11 300759 Thermal and Fluid Engineering	Specialisation Core Unit 12 300488 Numerical Methods in Engineering	Specialisation Core Unit 13 300487 Mechatronic Design	Alternate Unit 2
300741 Industrial Experience (Engineering)					
4th	Autumn	301245 Final Year Project 1	Specialisation Core Unit 14 300056 Robotics	Alternate Unit 3	Elective Unit 3 (Level 2 or higher)
	Spring	301246 Final Year Project 2	Specialisation Core Unit 15 301000 Computer Aided Engineering	Alternate Unit 4	Elective Unit 4 (Level 2 or higher)

VII. CONCLUSIONS

In this study, we attempted to prompt discussions on employing more effective WIL practices in the mechanical engineering specilasation at WSU. Review of published work on WIL suggests that a successful program needs support of the leadership, resources and dedication of academic team.

Although most engineering schools in Australia provide WIL as a unit to students, embedding WIL from the first year by merging theory and practice can be much more effective. In an effective embedded WIL program, practical activities must align with learning outcomes and an evaluation and review plan is required to ensure high teaching quality and student engagement. Ideally the activities are designed and delivered in collaboration with an industry partner.

Mapping potential outcomes of different WIL activities against current competency standard for a professional engineer in Australia showed that including entrepreneurship training and involving students in projects with real world orientation in university or the industry are more effective than other WIL activities. However, a strategic mix of activities suitable for students at different levels of the program. Finally, to prepare engineering students for their future jobs in changing environment of the 21st century, WIL programs should consider and implement elements such as micro-placement, competitions and online projects.

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Student- centred approach: understanding engineering students from disadvantaged backgrounds

Marina Belkina
Western Sydney University, the College
Kingwood, Australia
m.belkina@westernsydney.edu.au

***Abstract*—In an increasingly interconnected and rapidly changing world, the role of a vibrant, creative and diverse engineering workforce is critical. To contribute to technological advancements, engage in global collaboration, solve complex problems, encourage a more social and leadership skill, it is necessary for future engineers to be more diverse in their racial, gender, and socioeconomic (SES) representation. Many Australian universities followed the recent government objectives aimed to increase participation in Higher Education (HE) and created courses and programs providing alternative pathways to HE for students from non-traditional and low SES backgrounds. However, students undertaking university pathway programs, such as low Socio Economic Background (SES) students, first in family, remote and mature students often have considerable commitments that are not directly related to the study, such as job and/or career responsibilities which significantly affect their ability to progress in the course.**

The purpose of this study is to explore the example of Western Sydney University's The College, specifically the experiences of non-traditional students from the university pathway program studying engineering and what factors have the most influence on their workload and study success.

Keywords—engineering pathway program, student's workload

I. INTRODUCTION

University pathway programs are important part of widening participation in Higher Education (HE) in Australia and around the world. Today, enabling education courses have become very popular and are offered almost at every Australian university and are key in implementing wider participation across all demographics. Typically the courses attract a diverse range of students, some with lower academic achievement (ATAR) that can have occurred for a wide variety of reasons, incomplete schooling backgrounds, international students and mature students. Another pathway to HE undertaking rapid growth is distance and online learning as the preferred form of education available for students who would otherwise not be able to participate in traditional face-to-face courses [7, 9, 12].

Students' workload during the first year in HE or preparatory course is a contentious issue which directly impacts on student's academic performance and retention rates. One interpretation of workload essentially equates it to the number of hours worked [8, 15]. In this case workload is measured as the number of contact hours for classes plus the time spent on independent study. However students undertaking university pathway programs, such as especially low Socio Economic Background (SES) students, first in family, remote and mature students often have job and/or career responsibilities which significantly affect their ability to study.

It is generally believed that students identified students entering pathways programs are less prepared for independent learning and monitoring their workload in HE. Literature and the discourse around students from low SES backgrounds in higher education often adopts a deficit conception in which these students are associated with low entrance scores, decreasing standards and academic struggle and failure [14, 16]. However the recent study [11] reveal that, contrary to the conception of these students as a 'problem', students from low SES backgrounds demonstrate high levels of determination and academic skills and that they actively seek high standards in their studies. These findings support observations from the Western Sydney University (WSU), the College where many students entering pathway programs found to have a strong academic potential, but due to heavy life commitments often experience some difficulties in their study.

The university pathway programs are designed to address non-traditional students' needs by providing more face-to-face teaching hours and extra support. Thus, the data from the student's interviews from the WSU, the College suggests that time management and time poverty - limited time for study – is a concern for many students. However, yet there is a lack of quantitative data underwriting student's workload directly and indirectly related to their study which causes a limited understanding of the learner's commitments and how this impacts on the time (and the quality of time) they have to devote to study. There is also no evidence to show how the factors affecting students workload such as time at work, traveling time and self-education time vary across courses with

differences in entry parameters (open access/no ATAR or low ATAR) and there is no information how the workload of student's studying online compared with the workload of students in a face-to-face courses.

This study explores the parameters affecting student's workload in the first year of university pathway programs at the WSU, the College. The quantitative data of the parameters affecting student's workload and the factors affecting student's success in the pathway programs are collected across three engineering pathway programs.

II. METHODOLOGY

The quantitative data were collected at the WSU, the College from three engineering courses: Standard Diploma in Engineering, Extended Diploma in Engineering and Associate Degree in Engineering. The parameters of each course are summarised in Table 1. Successful completion of the Diploma courses grants student entry into the second year of study in the Bachelor Degrees in Engineering at the Western Sydney University.

Table I

Program	Mode of delivery	Entry requirements	Length of study	Number of students participated in the study
Standard Diploma	Face-to-face	ATAR 50	12 months, full time	35
Extended Diploma	Face-to-face	Open access	16 months, full time	53
Associate Degree	Online	3 year industry experience	4 years, part time	21

The total 109 students agreed to participate in the study.

III. STUDENT'S CHARACTERISTICS

Diploma in Engineering Students

The typical College student is a school leaver. Students are drawn from western Sydney communities where higher education participation rates are low; many are first in family to attend university; and many are also from non-English speaking and/or migrant backgrounds. As a region, western Sydney has significant areas of low SES, which translates to WSU in comparison to the sector as having one of the highest participation rates of students from low SES backgrounds.

Associate Degree in Engineering Students

The students from Associate Degree in Engineering are mostly mature-age students working full time and only attending 2-3 days intensive face-to-face sessions at the College in the middle of the study term.

IV. DATA COLLECTION

The students were asked to complete the daily log book – the table where they record the time they spend to a different activities during the day, such as time for study, working, careering responsibilities, social activities etc. The data was collected during week 4 in the Second Term of the Diploma Program and during week 5 in the Quarter 3 of the Associate Degree Program.

The students' perception to success in academic pathway program was investigated using a ten-item scale. Students were asked to respond on a 10-point like chart scale from definitely non important or very important. The parameters, such as "curriculum design, class engagement, support services" were used. A measure of the perception of the success in the pathway program was computed by summing the scores from tem items.

V. RESULTS AND DISCUSSION

As a first step in data analysis from the students' diary, we excluded data of students who did not complete any parts of the questionnaires. In addition, the data were evaluated for irregularities. Specifically, we looked for anyone who responded to each survey item with the same answers (e.g., marked "0" for all time spend for the face-to face study). From 109 engineering student participants in this study, 72 valid data sets were analysed.

Student's workload

The analysis of student's workload was conducted from the student's diaries were students recorded the time they spend for the different activities during the week: from Monday to Sunday. The summary of the student's commitments during the weekday and the weekend for three programs – Standard Diploma in Engineering, Extended Diploma in Engineering and Associate Degree in Engineering are shown in Figure 1.

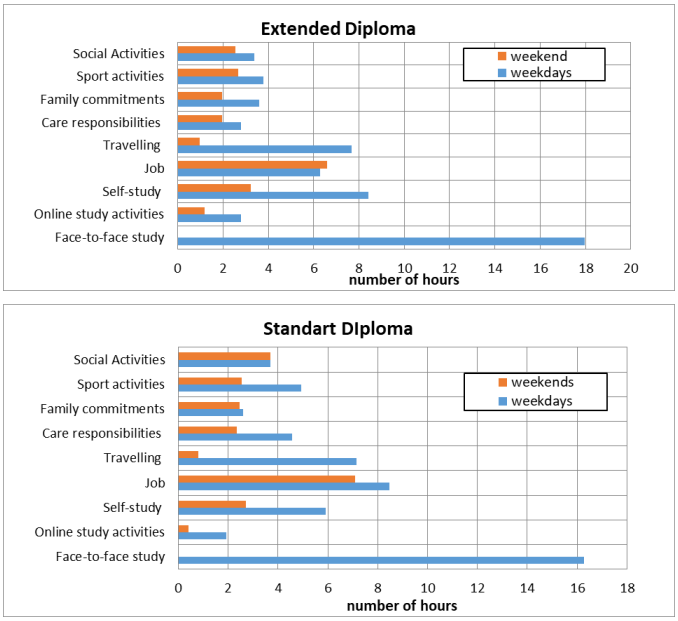

Fig. 1. The summary of the Diploma student's commitments during the week

As demonstrated in Figure 1, during the weekdays students from Diploma programs spent the largest amount of time for the face-to-face study at the College. The time is slightly higher for the extended Diploma students which correlated with their pattern of study during the term when the data was collected. Students from Extended Diploma indicated more time they spent for the self-study (5.9) compared to the students from the Standard Diploma (8.4 hours). The lager amount of time spent for the self-study by Extended Diploma students suggests that the students from an open access course are generally less prepared for the HE and require more time and effort to progress well in the study. The online activities associated with the online components used in particular subjects and shown as 1.9 hours for Standard and 2.8 hours for Extended Diploma during the weekdays.

On the weekends students indicated less time they spend on online activities and self-study compared to the weekdays and students from Extended Diploma show slightly larger amount of time they spend for study during the weekend compared to students from Standard Diploma.

Both Extended and Standard Diploma students indicated the large amount of time associated with the part time job with an average time of 8.5 hours on the weekday and 7.16 hours on the weekend for the Standard Diploma and 6.3 hours on the weekday and 6.6 hours on the weekend for Extended Diploma.

Many students indicated having care responsibilities, such as looking after siblings and parents/grandparents. The average time associated with care responsibilities are shown to be more on the weekdays which is usually related to the family responsibilities students have while their parents at work.

The significant amount of time students spend for travelling in both Standard and Extended diploma programs. And the much larger amount of travelling time during weekdays suggests that the most of time students spend to travel to and from The College.

The time associated with sport and social activities and other family commitments varies from 2 to 4 hours per week for both Standard and Extended Diploma and is slightly lower on the weekends than on the weekdays.

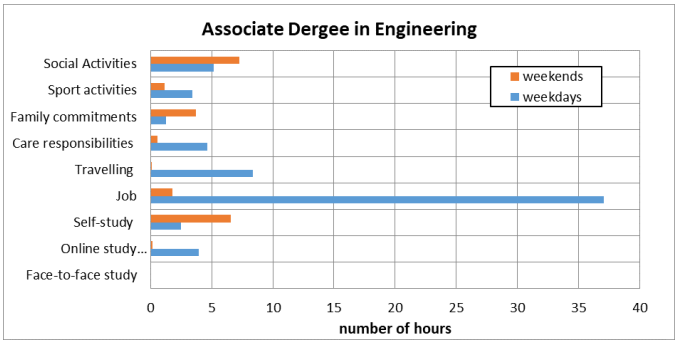

Fig. 2. The summary of the Associate Degree student's commitments during the week

Students from the Associate Degree in Engineering (Figure 2) spend 35 – 40 hours a week for the full time job. They attend online sessions during the weekdays and spend the most time for the self-study during the weekends. These student also indicated significant amount of time they spend for travelling (8.3 hours on the weekdays), but compared to Diploma students they have less care responsibilities (a total of 5.1 hours per week) and sport activities (a total of 4.4 per week). The students from Associate Degree indicated very small time they spend for work and travel during the weekends which allows them to spend more time on social activities (12.3 hours per week) and focus on self-study.

To demonstrate the overall picture of student's commitments associated with the different activities the total weekly time were summed and shown as percentage of the total time (Figure 3). The face-to-face, online and self-study were combined in one "study" category and care responsibilities and family commitment combined to the "family" category.

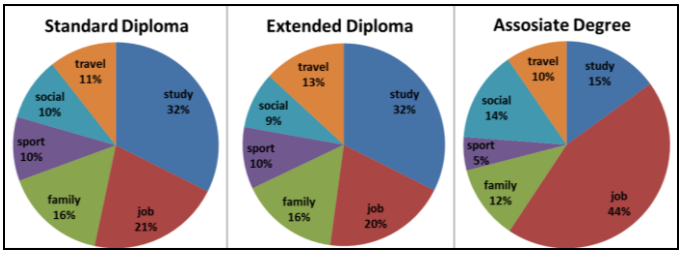

Fig. 3. The comparison of student's commitments towards the workload across three engineering programs

As shown in Figure 3, the students from the university pathway programs, such as Diploma and Extended Diploma in Engineering are required to spend significant amount of time which is not directly linked to their study, such as part time job, care responsibilities and travel time.

The above results raise an important message that non-traditional students, such as students from the low SES backgrounds, can be less successful in the HE not just because of the previous academic achievements, but also because of the significant time they are required to denote to the non-study commitment. These students often don't have a sufficient level of support from the family [5], and often need to support their family working part time or looking after young brothers and sisters.

In comparisons to Diploma Programs, the students from Associate Degree in Engineering course have a full time job and do the study online. While the total amount of hours the students denote to the job is doubled (44%, Figure 3), they still require less time for study – only 15%, compared to the Diploma students who spend 32% for study. Also Associate Degree Students spend more time for social activities, about 14%, while Diploma students often reported that they don't have many time left for social activities.

The majority of Diploma students began their pathway course directly or relatively soon after finishing secondary school. For many students, working while studying and sharing responsibilities with the parent are essential due to their financial situation.

The students from Associate Degree in Engineering are mostly mature-age students. They have accrued significant life experience in the labour market and in a domestic setting and having full time job the students are financially independent. These students demonstrate high motivation in the study which is determined by the employment benefits, such as future career opportunities and the improvement of the current job.

VI. FACTORS AFFECTING STUDENT'S SUCCESS IN THE PATHWAY PROGRAMS

The student success in the university pathway programs is influenced by a range of factors including motivation for study, student support within and beyond the institution, pre-entry preparation and curriculum congruence as discussed earlier [3, 4, 5]. Many institutions develop their courses and support services in order to provide the best opportunities to students to succeed in their study. To evaluate the importance and effectiveness of the main factors that commonly have influence on student's success in the pathway programs, the students from Diploma and Associate Degree programs were asked to respond on a 10-point like chart scale from definitely non important (1) or very important (10). The summary of student's responses is shown in Figure 4.

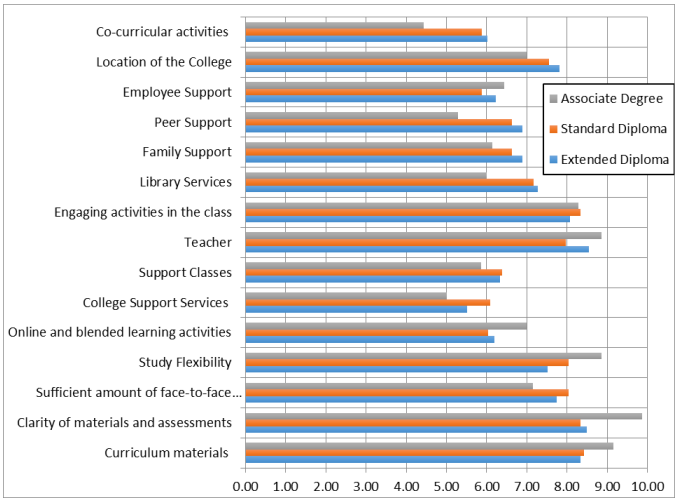

Fig. 4. Student's responses on the factors they determined being important to success in the pathway program

As demonstrated in Figure 4, the quality and the clarity of curriculum materials are the most important parameters for successful study identified by students. The students from Associate Degree indicated the clarity of materials as the top priority due to nature of the online education where the self-study dominates over the face-to-face sessions. The teacher characteristics that are also associated with engaging activities in the class are shown being important for students as well. As demonstrated earlier, the students from Diploma courses spend significant amount of time on part time work, travel and care responsibilities. While the study flexibility is shown being important for students, the sufficient amount of face-to-face classes is also shown as an important parameter for students from Diploma courses. This is because the typical students from pathway programs require more personal attention due to luck of HE skills, such as academic disadvantage, lower self-motivations and the ability to study independent outside the classroom. The mature students from Associate Degree indicated the preference of study flexibility over the face-to-face sessions. Compared to the Diploma students they also found less important institution support services, location of the College, family and peer support. These findings associated with the high level of independency of mature-age students and readiness to take initiative in self-education. Relatively less important factor students consider College's support services. While the extensive range of support services provided to the College's students, the effectiveness and relevance of some of the services should be better evaluated. The example of good practice in promoting students support services include collaboration with academics and engaging with their course content [1], developing one stop student support model [6] and inclusion of support strategies into curriculum [13].

VII. CONCLUSION

As demonstrated in this study, the journey for the non-traditional students in the university pathway program isn't always easy and overwhelmed with the large number of personal commitments that are not directly associated with the study. However even being in the group of considerable financial disadvantage and socio-economic status, the students found to be motivated, talented and willing to succeed in the course which evidenced by their successful progression towards university degree.

The cross-linking analysis of the main factors the students found to be imports in their successful progression demonstrate the importance of complex student-centred approach to support low-SES students studying in the pathway program.

This finding lends support to the notion advanced by some studies [2, 10] that the social and the economic components of the socio-economic status equation may have distinct and separate influences on educational outcomes. In overall, there is increasing evidence that pathway programs are helping to release student's potentials, making it possible for more students from diverse backgrounds to study for a university degree.

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A Review of Rainwater Harvesting in South East Asia

Que Thanh Trinh
School of Computing, Engineering and Mathematics
Western Sydney University
Sydney, Australia
q.trinh@westernsydney.edu.au

Ataur Rahman
School of Computing, Engineering and Mathematics
Western Sydney University
Sydney, Australia
a.rahman@westernsydney.edu.au

Md Abdul Alim
School of Computing, Engineering and Mathematics
Western Sydney University
Sydney, Australia
m.alim@westernsydney.edu.au

***Abstract*— Rainwater is considered globally as a sustainable and resilient source of water that can solve several issues such as increasing water demand, droughts, floods alongside contamination of groundwater and surface waters. Attention has been paid to rainwater harvesting (RWH) in the South East Asia (SEA) region, where the high potential of RWH can support livelihoods, food security and public health. This paper provides an overview of issues relating to the quality and quantity of harvested rainwater in SEA countries. It finds RWH could offer SEA countries various socio-economic and environmental benefits including agricultural irrigation, providing sustainable drinking water in rural areas and reducing stress on mains water supplies in urban areas. Besides providing evidence of the occurrence and implementation of RWH systems, future visions for studies on RWH in SEA are outlined in this review.**

Keywords—rainwater harvesting, South East Asia, quality, modelling

I. INTRODUCTION

In the context of global warming and climate change, freshwater scarcity has become a serious threat to sustainable development. Global demand for freshwater is rising due to increasing populations, improved living standards, shifting consumption patterns and the expansion of urbanisation and industrialisation. Amongst various alternative sources of water, rainwater is considered as a resilient source that can ensure water security [1]. Rainwater harvesting (RWH) involves a range of techniques for collection, storage and treatment of runoff from rooftops, purpose-built catchments and/or natural catchment, for both potable and non-potable uses. RWH systems can range in size from a small single dwelling to large scale premises that enable to provide quality water at an affordable cost. In fact, RWH not only contributes to drinking water savings and reduces reliance on mains water supplies in urban areas, it also enhances water availability for domestic and agricultural needs in remote and rural areas in both semi-arid and humid regions [2].

The advantages of RWH to the environment and communities have been recognised by many developed countries. However, the use of rainwater has not been widely accepted as a reliable alternative in most developing countries in South East Asia (SEA), where freshwater plays a critical role in supporting livelihoods, food security and public health. Moreover, most SEA nations adopt the implementation of RWH in an old-fashioned, ineffective, unsafe and unregulated ways due to socio-economic issues and cultural practices [3].

Studies on RWH have been carried out worldwide in the last few decades, with broader coverage of sustainable development aspects such as water conservation, water supply, stormwater management, urban agriculture, economic analysis and environmental issues [3,4]. However, there is limited knowledge of these special issues of RWH in SEA countries. In this regard, this paper provides an overview of rainwater harvesting in SEA that focus on quantity, quality, economics and regulations related to RWH systems with recent advances in rainwater assessment using continuous simulation water balance modelling.

II. RAINWATER HARVESTING IN SOUTH EAST ASIA

A. Current water issues

South East Asia (SEA) covers about 4.5 million km^2, which is 10.5% of the total Asian continent's landmass, or 3% of the Earths total land area. With a total population of more than 641 million, this represents roughly 8.5% of the global population. It is the third most populous geographical region in the world after South Asia and East Asia. The region is culturally and ethnically diverse, with hundreds of languages spoken by different ethnic groups. In contemporary political divisions, South East Asia consists of 11 nation states: Brunei, Cambodia, East Timor, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam [5]. Over the past four decades, the number of studies on RWH have notably increased. According to the Scopus database, over 2000 publications from around the world were identified via the keywords "rainwater harvesting", of which studies on SEA countries amount to around 100 documents including books and journal articles (Fig. 1) [6].

Rainfall in SEA is much greater than many other region of the world due to the Asian monsoons. The countries in this region are characterised mostly by floods and typhoons, but human-induced climate change has altered rainfall patterns, especially the timing of the start of the monsoon, causing frequent drought, failed crops and famine [7]. For example, the

severe drought in 1998 triggered the Malaysian government to promote RWH as an alternative resource to reduce over-dependence on river and other surface waters, which resulted in various policies and guidelines for RWH systems being implemented [8]. In addition, a household's tendency to buy bottled water in rural areas and the domestic use of rainwater in urban areas is constrained by local attitudes in the Mekong Delta in Vietnam [9,10], and Indonesia [11]. Moreover, an estimated 13% of urban and 42% of rural Cambodians lack access to an improved drinking water source, whilst the remainder of the population cannot rely on groundwater containing highly hazardous arsenic and microbial contamination [12]. Therefore, rainwater is considered as a traditional and sustainable water source for south-eastern Asian communities.

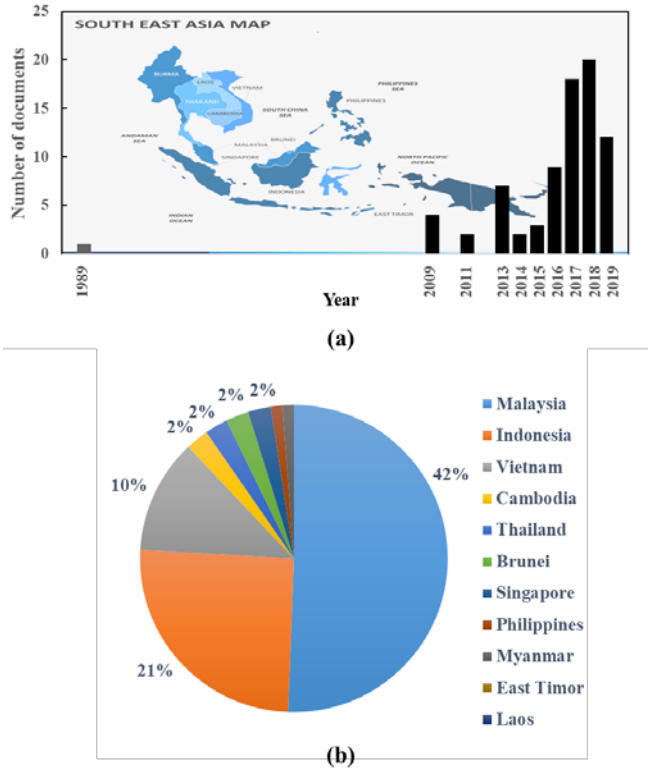

Fig. 1. (a) Publications of RWH topic from 1989 to 2019, (b) SEA countries publishing RWH [6].

B. *Quality of harvested rainwater*

Rainwater is relatively clean but can become contaminated from leaching of the roof materials and deposition on roof surfaces. In older systems, the commonly used roof materials were steel, copper, aluminium, zinc or tin. Overtime, the roof materials become rusty and further corroded by rainwater, which is normally slightly acidic, pH ~5.6 [13]. In addition, protective materials (e.g. paint, tar, glue, sealants) used to increase roof life span may contribute additional contaminants to collected rainwater. Moreover, there are various types of tanks with various materials such as polyethylene, concrete, galvanized steel, fiberglass and stainless steel, which tend to rust overtime and could release certain chemicals to water. Research on the variations in rainwater quality from roof catchments was carried out by Yaziz [14] in the late 1980s showing high metal content in rooftop rainwater and first-flush volumes of 5 litres as the minimum requirement to significantly reduce microbiological contamination [14].

The quality of rainwater harvesting in SEA countries for domestic and potable purposes has been reported as satisfactory as per WHO and Malaysian government standards and was recommended to be safe to drink [15,16]. However, microbiological parameters (total coliform, fecal coliform and E. coli) were found to exceed the drinking water standards, due to poor hygienic practices of the RWH systems [16]. The presence of potential pathogens in the freshly harvested rainwater from different roofing materials has also been confirmed by a recent study in Singapore [17]. Another study showed contradictory findings about the bacteriological quality of rainwater in rural northeast Thailand, which claimed that rain-jar water was much purer than drinking water from alternative sources [18].

Another investigation in the Mekong Delta, Vietnam found that local conditions (e.g. roof types, storage system, retention time) and spatial conditions (e.g. proximity of industry, main roads, coastline) can have an adverse effect on the quality of harvested rainwater [19]. Moreover, rainfall intensity and the number of dry days preceding a rainfall event significantly influence the quality of runoff from RWH systems. These constraints to water quality may be overcome by introducing first flush technology [20], roof pitch gradient and more environmentally friendly materials [21]. Commonly used treatments in RWH systems are pre-storage filtration systems, for instance, simple filtration preventing mosquito larvae from entering rainwater storage tanks [22,23], corn cob activated carbon filtration [24], microfiltration and ultrafiltration units that can remove bacteriological loads [25]. Other treatments are able to extend harvested rainwater quality to potable uses, including photocatalytic and adsorption treatments [26].

C. *Modelling rainwater harvesting system*

The basic tool commonly used to assess rainwater availability is Water Balance Simulation Model (WBSM) which considers various factors such as tank size, daily rainfall, losses, daily water demand, mains top up and tank spillage on daily time scale [3]. Optimisation of RWH system in order to maximise its benefit often links to tank size and runoff coefficient values. Nowadays, in support of the modelling, spatial information and satellite image analysis, geographic information system (GIS) approaches and remote sensing technology have been adopted to detect potential roof areas for harvesting rainwater [27]. Hence, water savings, reliability and financial viability of RWH systems can be estimated with reasonable accuracy [3,27].

A number of successful projects of RWH were carried out in SEA using integrated modelling tools. For example, Radzali

[28] developed roofing layers using high resolution satellite imagery acquired from WorldView-3 satellite systems with 0.3 m of spatial resolution to obtain spectral and spatial information of buildings and roofs in an urban area of Malaysia [28]. Specifically, the behavioural performance assessment of WBSM for RWH systems in SEA tropical monsoon regions should also consider any additional water availability linked to the diversity of monsoon patterns [29].

While many works have focused on modelling of small scale rainwater harvesting for various sectors such as residential and commercial, there is very little information about large scale rain water harvesting system, particularly in SEA region. The only case study of large-scale RWH system which served the Malaysian eco-community of 200 houses with an average 4 occupants per household involves comprehensive site-planning, systems planning and design. Optimal size of the storage tank, rooftop area, reliability and water savings analysis in large-scale system was developed as similarly as the small-scale type. The analysis showed that roof area and water demand would significantly affect the storage tank size, and water savings [30].

D. Implementation of RWH in South East Asia

Sufficient precipitation is a powerful element driving innovation in RWH, especially in relation to agricultural needs. The concept of RWH in wet seasons and supplying it to crops in the dry season has been introduced widely in SEA countries. In Indonesia, rainwater from the roof of a greenhouse periodically harvested in the wet season, stored in torrents and applied as fertiliser-irrigation supply during the whole year (wet and dry season) on red tomato cherry plants [31,32]. Rainfall-runoff analysis indicates that rainwater harvesting as a source of farming irrigation can improve dryland cocoa cropping index [33,34].

Besides benefits to quality and quantity, rainwater is easily accessed in a decentralized manner, which makes it a preferred choice in rural areas. Rainwater is also suitable for remote and semi-arid regions, where access to drinking water is scarce. A well-designed rainwater harvesting system for drinking water has been successfully operated at an elementary school near Hanoi, Vietnam, which demonstrated the potential to promote drinking rainwater in rural areas of developing countries [35,36]. Further, new concepts in sustainable development with rainwater and renewable energy have developed been combined at the site of Biodiversity Conservation Centre in Cambodia, which provided an intelligent water-energy management with quality drinking water [25].

In urban and peri-urban areas of Malaysia, implementation of RWH systems often compete with limited land for household and commercial buildings. Space-saving approaches include the use of RWH tanks such as the VODA tank, Thin tanks, Rainwater HOG, Water Butts and Rainwater Bladder Tank are installed at different locations, e.g. balcony, external walls, backyard or near the side of fences [37]. Moreover, the use of integrated water systems such as hybrid rainwater-greywater decentralised system have become popular in urban areas [38,39,40], but its occurrence and contamination require an urgent need for integrated and standardised storage, utilisation and treatment strategies.

III. Future Study in South East Asia

RWH has been successfully implemented in the humid and tropical SEA countries, especially in Malaysia (138 to 181 rainy days per year) [3,41]. The success of RWH systems is greatly dependent on the quantity and temporal pattern of rainfall. In addition, it is important to put into account the spatial variation of rainfall and monsoon patterns when assessing the RWH potential to obtain the biggest water savings.

Despite the abundance of rain all year round, the cost is a problem when applying RWH for several SEA countries. Economic performance measures showed that RWH is currently infeasible in Brunei with capital costs and water prices being among the prohibiting factors. To remedy this, a combination of rebates on capital costs and raising current water prices has been suggested as a possible solution [42]. Optimising RWH system designs is crucial to reduce operational and maintenance costs and to prevent system failure. For example, designing RWH systems using gravity has better cost benefits compared to systems with pumping mechanisms. Also, material selection can also reduce the establishment costs and ensure better water quality.

The benefits of installing RWH systems are more attractive when it is implemented early during the design and construction phase, as opposed to retrofitting of existing buildings. The savings from implementing RWH in large commercial buildings are more rewarding compared to small-scale installations in houses. Moreover, implementation of RWH systems in the foreseeable future should be applied more intensively for large-scale communities with treatment processes to meet both potable and non-potable water demands.

IV. Conclusion

This paper reviewed the implementations of RWH in the SEA region. The wider implementation of RWH is timely because of today's water issues linked to environmental changes, increasing demands, contamination of groundwater and surface waters. The variations in quality of harvested rainwater depends on materials (roof catchment and storage tank), maintenance and the climatic conditions. Minimal treatment is required for non-potable uses, while suitable treatment processes needs to be applied for potable purposes to meet drinking water guidelines. Development of design curves for the RWH system assists wider application in a region without the need of on-site data analysis. Integrated use of spatial technology will make RWH system modelling more

effective in identifying roof areas and other impervious areas as well as flood-prone areas for urban flood mitigation.

It is proven that RWH could offer various socio-economic and environmental benefits such as agricultural irrigation supply, providing sustainable drinking water in rural areas, and reducing over dependence on mains water supply in urban areas. Future research on RWH should focus on financial analysis covering multiple benefits, life cycle analysis incorporating renewable energy, environmental friendly materials and smart design of RWH systems to serve not only single household but also large-scale communities. A simple Apps can be developed to design and analyse RWH for SEA region.

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Life style, its elements and their universal relevance to wellbeing

Vojislav Ilic

School of Computing, Engineering and Mathematics, Western Sydney University, Sydney, Australia
v.ilic@westernsydney.edu.au

***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—life style, health, prevention, education

PARTNERSHIP PEDAGOGY PATHWAYS FOR THE FIRE PROTECTION INDUSTRY INTO MAINSTREAM POST-GRADUATE PROGRAMS

Grahame Douglas and Swapan Saha

School of Computing, Engineering and Mathematics, Western Sydney University, Sydney, Australia.

Abstract - In Australia, the fire protection industry provides an essential service in the safety of residences and workplaces from the potential impacts of building fires. The industry is characterised by many thousands of small-medium enterprises. The professional industry body is the Fire Protection Association of Australia which has a national reach of 1,500 businesses with a cohort of 30,000 individuals who are serving the fire protection industry. Government inquires and reviews have consistently identified the need for improved education and compliance for the building sector and for fire safety design in particular. From October 2017, the NSW government introduced requirements for competent persons to operate under a fair trading regulatory model within the fire protection industry. The existing cohort is largely trade qualified and the intention of the regulator is to provide for industry to accredit fire safety practitioners in areas of design, installation, servicing and auditing or fire safety systems in buildings. Western Sydney University has embarked on a blended learning platform for the delivery of three core industry competencies to support industry standards and as a pathway to entry into a possible fire safety design post-graduate program based on demonstrated knowledge and workplace experience. This project aims to develop a platform in collaboration with the FPAA and NSW Fire and Rescue using a collaborative and partnership pedagogy framework in which the FPAA and Western Sydney University will provide a micro-credential which can be used in conjunction with other formal training in support of regulatory expectations and industry needs. This project also illustrates that this sort of program can be used to improve the knowledge and understanding of other professionals in the building sector including architects, engineers, building managers and certifiers.

I. Introduction

The fire protection industry is an important aspect of the construction industry and provides essential fire safety services for class 2-9 buildings under the National Construction Code (ABCB 2019). Recent inquiries into the construction sector has identified major limitations with the delivery of building works, including those associated with fire safety in Australia [1].

The failure to address fire safety provisions can have both potentially fatal outcomes as well as significant cost implications for future residential where safety systems, including fire safety, have not been adequately addressed. In 2012, a fire in a Bankstown apartment block which did not conform to the NCC, resulted in the death of one woman and serious injuries for another when they attempted to jump from a fire in their unit [2].

In Australia, fire protection systems are designed either to comply with the deemed-to-satisfy provisions of the NCC or may be designed in accordance with the performance provisions of the NCC by qualified fire safety engineers. However, fire safety engineers may not be involved in the actual installation of these systems.

Since 2016, the industry has, through the Fire Protection Association of Australia, sought to improve the quality of design, installation, maintenance and auditing of the fire protection practitioner through its FPAS accreditation scheme [3].

The Fire Protection Association of Australia (FPAA) has a national reach of 1,500 businesses with a cohort of 30,000 individuals who are serving the fire protection industry, with many more individuals operating outside the Association. From 1 October, 2017 the NSW Government has introduced a requirement for 'competent persons' to operate under the 'fair trading' regulatory arrangements. This could be extended to other jurisdictions. This regulatory framework has introduced a requirement for both customer protection and accreditation associated with the delivery of this essential service. The nature of the industry is that it has developed in an ad hoc fashion with government now requiring improved standards of customer protection and safety. Operators interact with building surveyors and engineers (including civil, mechanical and fire safety engineers) as well as architects, building managers and residents.

Since major fires have occurred at Docklands in Victoria [2] and more significantly with the loss of life in Grenfell (UK) [1], building owners, body corporates, project managers as well as designers and certifiers are seeking to improve their skills in fire protection. The provision of appropriate and relevant levels of education is therefore needed, as well as pathways for progression within the construction industry and regulatory framework being adopted by both industry players and regulators alike.

To assist the construction industry and the community, Western Sydney University has embarked on the development and implementation of an educational framework which is tailored to the current skill set of the industry, as well as providing pathways for para-professional skills and competencies. This framework is based on the National Training Package Diploma of Fire Systems Design (Training.gov.au) under the 21C Makerspace program.

This paper considers the implications of public inquiries, reviews and recent regulations which give rise to the development of education strategies for the fire protection industry in NSW (and Australia more broadly). It then considers the pedagogical considerations and pathways being developed by Western Sydney University (WSU) in response to the environmental scan of the construction industry and expectations of the community and government in the delivery of safer buildings in relation to fire safety systems design and operation.

Keywords - Fire protection, blended learning, building, partnership pedagogy, micro-credential.

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Exploration and Practice on Cultivation of Internationalized Talents of Civil Engineering Based on English-Taught Major Development

Jing Ji
School of Civil Engineering &Transportation
South China University of Technology
Guangzhou, China
cvjingji@scut.edu.cn

Ying Liu
School of Civil Engineering &Transportation
South China University of Technology
Guangzhou, China
932794608@qq.com

Chaolu Zhuang
School of Civil Engineering &Transportation
South China University of Technology
Guangzhou, China
847773538@qq.com

Jing Li
School of Civil Engineering &Transportation
South China University of Technology
Guangzhou, China
cvjingli@scut.edu.cn

Jianrong Pan
School of Civil Engineering &Transportation
South China University of Technology
Guangzhou, China
ctjrpan@scut.edu.cn

***Abstract*—The export-oriented Civil Engineering talents with international vision are needed for the implementation of "The Belt and Road" strategy in China. The adoption of English-Taught in undergraduate education is an important measure for the cultivation of internationalized talents. Based on English-Taught major development, exploration and practice on training Civil Engineering talents with broad international vision and communication are carried out from the aspects of the teaching staff training, the English-Taught curriculum, the international practice courses and the international joint training programs, the detailed development plan, implementation model and the effects achieved are presented.**

Keywords—Civil Engineering, Internationalization, Talent training, English-Taught major development

I. INTRODUCTION

"The Belt and Road" is a major strategic conception of China's opening up to the outside world in the new period, the important part of which is to promote the infrastructure construction of countries along the route [1]. With the promotion of "The Belt and Road" strategy, it is bound to drive more domestic infrastructure investment and construction enterprises to the international market, followed by the urgent demand for export-oriented talents with international vision. At present, it is urgent to train a large number of international Civil Engineering talents who have a sense of social responsibility, are proficient in foreign languages, are familiar with international rules, have an international perspective, and are good at seizing opportunities and striving for initiative in global competition.

The adoption of English-Taught in undergraduate education is an important measure for the cultivation of international talents. Full-English teaching has become an important trend of the teaching reform in colleges and universities in China, A large number of these institutions have gradually implemented Full-English teaching in different professional fields, and achieved a series of gratifying results [2]. However, due to the limitations of Civil Engineering discipline, it is difficult to conduct Full-English teaching, and even more difficult to set up the English-Taught major in Civil Engineering.

Facing the huge development opportunity brought about by "The Belt and Road" strategy, the South China University of Technology has taken the lead in carrying out the exploration and practice of English-Taught major development in Civil Engineering in colleges and universities all over the country. A series of measures have been taken in the teaching staff training, the English-Taught curriculum, the international practice courses and the international joint training programs, in order to systematically train excellent innovative talents in Civil Engineering with broad international vision and good international communication ability, and thus improve the quality of internationalized talents training in an all-round way.

II. Necessity of English-Taught Major

The driving force for English-Taught major development in Civil Engineering is mainly from three aspects: the demand for international talent training, the demand for international joint training programs, and the training needs of foreign students and international exchange students. It can also promote the level of international teaching staff and the reform in education of Civil Engineering, as shown in Fig. 1.

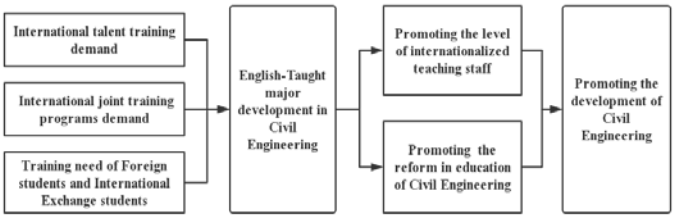

Fig.1 Necessity of English-Taught major.

The first is the demand for international talent training. With large domestic Civil Engineering construction enterprises and design institutes entering the overseas market, and large foreign Civil Engineering consulting companies entering the Chinese market, there is an urgent need for a large number of high-quality Civil Engineering talents with strong innovative ability, international vision and communication ability, and high English level. English-Taught major development in Civil Engineering will help to bring more talents to the communities.

The second is the need for international joint training programs. In order to make full use of foreign high-quality educational resources, Civil Engineering majors urgently need to cooperate with well-known foreign universities to carry out international joint training projects at all levels for undergraduate, master and doctor training. English-Taught major development in Civil Engineering will not only contribute to the smooth development of these projects, but also contribute to attract better quality projects.

The third is the training need for foreign students and international exchange students. With the promotion of "The Belt and Road" strategy and the rapid development of infrastructure construction in China, the number of foreign students majoring in Civil Engineering in colleges and universities in China is increasing year by year, and the demand of Civil Engineering students from Europe, the United States and other developed areas to study in China is also increasing. English-Taught major development in Civil Engineering will help to accept these international students and exchange students, and demonstrate the "soft power" of Civil Engineering education in China.

Through English-Taught major development in Civil Engineering, we can also effectively promote the level of internationalized teaching staff. On the one hand, we can step up efforts to attract famous overseas teachers to teach undergraduate courses in China on a regular basis, on the other hand, we can promote domestic teachers to study abroad through various channels and improve their teaching ability in English. Take talent training as a link to promote substantive and sustainable international exchanges and cooperation between teachers at home and abroad.

Through English-Taught major development in Civil Engineering, a number of influential achievements in education and teaching reform can be systematically cultivated and produced. It includes the reform and innovation of talent training program, English-Taught teaching materials, high-quality courses, the innovative practical teaching mode and so on.

III. Program of English-Taught Major

English-Taught major in Civil Engineering is designed to explore the training model of international innovative talents. While paying attention to training students in mathematical mechanics, basic structural theories and design methods, advanced construction technology and engineering management knowledge, we should strengthen the whole process of English teaching and strengthen the practical teaching links at home and abroad, and train excellent innovative talents in Civil Engineering with good comprehensive quality of humanities, science and engineering, international vision and communication ability, which is in line with the talent training mode internationally.

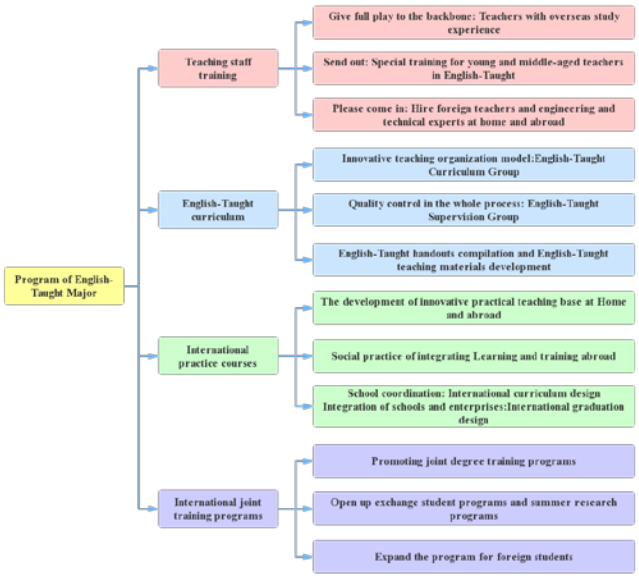

Fig.2 Program of English-Taught Major.

Centering on above development objectives, this paper makes an in-depth comparative study on the undergraduate training programs of Civil Engineering in 17 similar universities at home and abroad, on the basis of which the program of English-Taught major construction in Civil Engineering is put forward, as shown in Fig.2. The development plan covers the teaching staff training, the English-Taught curriculum, the international practice courses and the international joint training programs,which runs through the concept of international talent training with the combination of innovation and practicality.

IV. Measures of English-Taught Major

A. "1+1+1" Internationalized teaching staff training

The teaching staff training is the fundamental condition for the English-Taught major development. For the major of Civil Engineering, there is an urgent need for a team of teachers with a good international background and familiar with engineering education. Relying on the existing teaching staff,an internationalized teaching staff has been gradually formed by the South China University of Technology,with responsible professors as the core and young teachers studying abroad or preparing to study abroad as the backbone,and famous overseas teachers and first-line technical experts as the supplement.It can be summarized as "1+1+1" teaching staff training mode.

The first "1" refers to a current teacher who has more than one year's experience of studying abroad or visiting abroad. There are more than 40 teachers in this part,most of whom have the experience of engineering practice at the same time. After short-term preparation and training, this part of teachers can directly undertake the teaching tasks of English-Taught curriculum and international engineering practice.

The so-called the second "1" refers to young and middle-aged teachers who are gave English-Taught curriculum and trained abroad.These teachers are selected to train abroad,focusing on improving their English teaching ability and learning advanced teaching methods abroad.In recent years, more than 10 young and middle-aged teachers have gone to the United States, Britain, Canada, Australia, the Netherlands, Singapore and other countries to complete the English-Taught curriculum training.And then these teachers began English-Taught curriculum.In addition, teachers who go abroad for further study in other ways are also required to complete scientific research and strive for time to learn some relevant courses and collect relevant teaching materials, so as to lay a solid foundation for undertaking English-Taught curriculum after returning to China.

What is called the third "1" refers to the foreign teachers and first-line technical experts employed. An average of 7 to 8 foreign teachers with rich teaching experience are hired each year to teach some undergraduate courses, and at the same time, domestic and foreign front-line technical experts are hired to teach some strong practical professional curriculum.In this process, teachers of relevant courses in this major and foreign teachers prepare lessons together and participate in tutoring students, from which they can also learn advanced foreign teaching concepts and improve their English teaching ability.

In order to comprehensively enhance the English-Taught teaching ability of young and middle-aged teachers,English-Taught demonstration courses and seminars are also regularly be organized to explore and share English-Taught teaching methods so that more teachers can benefit from them.In addition, famous overseas teachers and front-line technical experts from domestic and foreign enterprises are also hired to train these teachers in practical teaching ability. For example, for two years in a row, professors from the University of Liverpool in the United Kingdom have been hired to teach young and middle-aged teachers practical teaching for foreign undergraduates and master's degree students, and to share the experience of how foreign universities have close relationship with the engineering community in practical teaching. It is of great significance to the practical teaching reform of teachers in this major.

B. Innovative Teaching Mode——English-Taught Curriculum

English-Taught curriculum development is the core task of English-Taught major development. In addition to the series of political courses, cultural quality education courses and physical education extracurricular courses in the public basic courses, most of the other public basic courses, subject basic courses and professional field courses in the Civil Engineering of South China University of Technology adopt English-Taught. A small number of courses are transitioned by bilingual teaching.A series of measures have been taken in the English-Taught Curriculum Group,the English-Taught Supervision Group and the English-Taught teaching materials,in order to carry out English-Taught curriculum development in a down-to-earth manner.

For each English-Taught curriculum offered in this major, a curriculum team consisting of 2 to 3 professional teachers and 1 overseas teacher has been set up, which is responsible for all teaching activities, ensuring the equality of responsibility, power and benefit. The so-called responsibility refers to responsible for the development of teaching materials, the preparation of curriculum materials, curriculum teaching and assessment, teaching situation summary and the employment of foreign teachers and so on. What is called power is the independent control of the supporting funds for curriculum development, the recommendation of teachers to colleges or schools for overseas training, and so on. The so-called benefit is all kinds of resources used for curriculum development, including all kinds of stock resources and competitive incremental resources, which are controlled by the curriculum group.

In order to control the teaching quality of the English-Taught curriculum in an all-round way, the College has set up an English-Taught Supervision Group with the Vice President in charge of undergraduate Teaching as the team leader and the member of the College Teaching steering Committee and the Director of the Teaching and Research Department as the members. The supervision group plays a supervisory and guiding role in all aspects of English-Taught curriculum teaching, such as organizing lectures by leading teachers before class, listening in class, participating in teaching evaluation after class, and so on, so as to improve the teaching quality of English-Taught curriculum in the whole process.

In terms of English-Taught materials,As far as possible, choose the original foreign English textbooks (such as material mechanics, Civil Engineering materials, steel structure theory, foundation engineering, etc.).Or select the imported domestic English textbooks (such as structural mechanics, soil mechanics,etc.),so as to give students authentic English textbooks.However, due to the particularity of Civil Engineering, the original foreign textbooks of some professional courses are far from the domestic situation in standardizing the use of standards, which does not meet the teaching requirements of domestic courses. Therefore, teachers are also actively encouraged to collect and refer to the original European and American teaching materials, combined with national conditions,then write curriculum handouts, in order to meet the needs of classroom teaching. At present, there are six English-Taught curriculum using teacher-compiled handouts, some of which have been used for four consecutive sessions, with good results.

C. International Engineering Practice Education with Cooperative Innovate Mode

International engineering practice education is an important part of civil engineering English-Taught development, which is an important way to train students to have an international vision and be familiar with international rules. The South China University of Technology has actively opened up overseas practice bases and explored the education model of international engineering practical, and great results have been achieved.

1) Development of Innovative Practical Teaching Base.

On the basis of more than 20 out-of-school practice teaching and practice bases in China, this major has further opened up three overseas practice bases, including internationally famous design consulting companies, large construction enterprises and real estate management companies. The business scope of these enterprises covers all aspects of civil engineering design, construction and management, and can provide students with a full range of practical training.

2) Exploration of Innovative Practical Teaching Mode.

This major always runs through the international engineering practice education in all the practical teaching links, including the lower-grade students' social practice and engineering experience at home and abroad.It also includes senior students production practice, curriculum design, graduation practice and graduation design and other links, these links are completed under the guidance of teachers from both schools and enterprises.The three links are as follows: overseas social practice, international curriculum design and graduation design.

3) Social Practice of Integrating Learning and Training Abroad.

Overseas social practice and engineering experience are added in the second academic year, in order to enable students to understand the operation of the overseas Civil Engineering industry, investigate and learn advanced management experience and corporate culture abroad. As well as advanced environmental awareness and sustainable development concept. Students of grades 2011, 2012 and 2014 use their sophomore summer to carry out social practice and engineering experience in Hong Kong. Visited major projects such as Zero carbon World, Tolo Highway widening Project, HongKong-Zhuhai-Macao Bridge site, West Kowloon High Speed Rail Station, Golden Gate Industrial Park, Harbour purification Phase II Project and Stonecutters Island sewage treatment works, etc. These students are also visited enterprises and universities such as Arup International Design Consulting, the University of Hong Kong, the City University of Hong Kong and the Hong Kong Polytechnic University. The students of Grade 2013 went to Macau to participate in social practice and engineering experience activities, visited the University of Macau and the Macao landing site of the HongKong-Zhuhai-Macao Bridge, and held discussions with representatives of outstanding engineers in Macao. After several years of exploration, a set of standard process for overseas engineering practice has been gradually formed, as shown in Fig. 3.

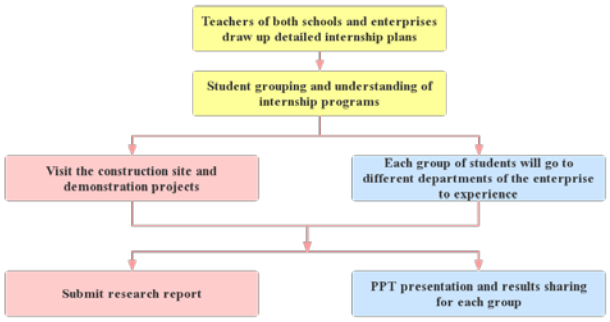

Fig.3. Standard process of overseas learning and training for engineering practice.

4) School collaborative international curriculum project.

From 2015 to 2016, a web-based course design project was launched by the major and the University of Coventry in the United Kingdom. Under the guidance of the teachers of both sides and the engineers of the international design consulting company, the students from two schools was required to initiate a curriculum design team and cooperate to complete the design of an actual engineering project. The students gradually build the unique perspective of an engineer on the actual engineering project in the early stage of the design by exchange and study with the engineers of well-known international design consulting firms such as Arup and Atkins. With the progression of the curriculum design, the online meetings with foreign students twice a week have further strengthened the students' English communication ability and sense of teamwork. More importantly, many opportunities are provided for student to learn and use European norms for structural design through this training of international curriculum design, their knowledge and understanding of the similarities and differences between domestic and foreign norms will be broaden and deepen.

5) School-enterprise integration of final year program.

As we all know, the graduation project is the last and most important link of concentrated practical teaching in the undergraduate stage, so a series of reforms are carried out in this major in order to make the graduation project closer to the actual project, and more practical and innovative to students. One of the important reforms in the graduation project is the implementation of the double tutor guidance system inside and outside the school. Arup, a famous international design consulting company abroad, was chosed as one of the joint training units of the school and enterprises, and we also hired 10 senior technical or management personnel in this company as the out-of-school instructors for the graduation project. The graduation project topics personally proposed by these 10 business mentors are derived from the actual engineering projects, involving structural design, project research and project management, as shown in Table 1.These business mentors are demand to set aside 1 to 2 unit time a week to guide students to help them improve their ability to apply what they have learned by analyze and solve problems from the perspective of practical engineering. In addition, each business mentor is equipped with an in-school teacher to assist in mentoring, with emphasis on young teachers. Moreover,in the process of guiding students, these young teachers in the school and business mentors have been trained in the actual engineering projects to improve their ability of practical teaching effectively.

D. Joint Training of Omni-Directional and Multi-Level Internationalization

International joint training is an important supplement and extension of English-Taught major development, the development of English-Taught major has also laid a good foundation for international joint training. In recent years, both in quantity and quality ,the internationalization projects of civil engineering major in South China University of Technology (SCUT) have made great breakthroughs.These programs include degree joint training programs,exchange student programs, summer short-term study programs, and admission programs for international students.

TABLE I. GRADUATION PROJECT TOPICS GUIDED BY MENTORS OF ENTERPRISES IN 2017

student	Graduation project topic
A	On adopting Knowledge and Innovation Management in building and construction companies in China.
B	Review on recent studies of train-track-bridge coupling vibration .
C	Project Management Methods - which one is best for my project?
D	Critical item comparisons of concrete structure design codes among GB50010, EC2 and CoPHK2013.
E	Research on the operation and the demand service of themed smart community.
F	Plate isogeometric stochastic analysis.
G	How can building and construction related companies maintain competitive edge in China through effective knowledge management?

Many degree joint training programs are set up in this major ,including the "2+2 undergraduate double degree" program, the "3+1+1 or 3+2 bachelors-master's degree " program, the "1+1+1 double master's degree" program and the "3+1+n master-doctor's degree " program, etc. More than 10 world-class universities are cooperating with us, such as the University of Illinois in the United States, the University of Birmingham in the United Kingdom, Delft University of Technology in the Netherlands and the University of New South Wales in Australia. The development of English-Taught major has effectively promoted the establishment of these high-quality international joint training programs, but also greatly improved the competitiveness of students to participate in these projects. The smooth implementation of these projects has also provided a lot of valuable experience and inspiration for the professional development of the English-Taught major at the same time.

The exchange program give chance to student that they can go to colleges and universities outside the country to study courses and experience local life and culture without paying

extra tuition fees, which cause it become the most popular exchange program for students. However, for a long time, the exchange program has been difficult to promote for colleges and universities. The underlying reason is that our Chinese teaching environment limits the peer-to-peer exchange of college students on both sides. Nowadays, a good conditions for the promotion of exchange student projects has been created by Civil Engineering English-Taught major development. We have signed a "3+1 exchange student" program with the University of Western Ontario in Canada. The exchange students of this major study free of charge at the University of Western Ontario for one year. As a condition of equivalence, we also accept each other's students to study in this major, realizing the real exchange. For this reason, the project has been supported by the few undergraduate high-quality international exchange programs of the National study abroad Council , and also favored by students from each other's schools at the same time,. There are six students from the University of Western Ontario came to study as exchange students in 2016, and seven students will take part in the exchange in 2017. In addition, this major has signed a one-semester credit program with the University of Birmingham in the United Kingdom and the University of Pittsburgh in the United States, and a one-semester exchange program with colleges and universities in South Korea, Taiwan, Hong Kong and Macao. A good international atmosphere for the Civil Engineering English-Taught major development have been created by these exchange student programs

A summer holiday research programs has also signed with a number of universities in Canada and Australia, which let students carry out research work for a period of three months under the guidance of teachers in each other's colleges and universities. Beside, students of this major also spend the summer holiday to attend the University of Illinois at Urbana-Champaign for three to four weeks of professional training. By joining these summer exchange programs, students have broadened their horizons, increased their knowledge, and benefited a lot from their studies, scientific research and life.

At present, the demand for civil engineering talents in the countries involved in the strategy is also gradually increasing with the continuous promotion of "The Belt and Road " ,the development of English-Taught major also plays a great role in attracting foreign students to study in China. Taking this as an opportunity, the major makes full use of the English-taught environment to educate foreign students positively in civil engineering. The number of foreign students who come from Indonesia, Malaysia, South Korea, Congo, Yemen, Tanzania, Peru, Saudi Arabia and more than a dozen countries has increased year by year, from 3 ~ 5 to 15 ~ 20 per year.After these students return home to work, they will have a far-reaching impact on the international influence of their major.

V. Achievements in English-Taught Major Development

Based on the Enghlish-taught major development, with six-year exploration and practice on international talents training, the civil engineering department of South China University of Technology (SCUT) had remarkable achievements in formation of teaching staff, development on English-Taught major's curriculum, education of international engineering practice and international joint training.

In the formation and development of teaching staff, leading by "1+1+1" mode and taking paths as "sending out" and "invitation", middle-aged and young staff were cultivated and their ability was enhanced in two aspects by the way of "burden". One is English-taught ability while another is internationalized teaching capacity. A group of young staff stand out through the process and grow up. Now, 40% of our teachers who have or almostly have the capacity of teaching in English have become a powerful support in the project. Meanwhile, the ability in international communication and cooperation of our department has been enhanced.

With respect to the development on English-taught curriculum, some English-taught courses were built based on the "curriculum group mode" which utilizes the experienced teaching skills and strong English using ability form different teachers. At present, among the public basis courses, 100% of them can be operated in English in addition to the politics, humanities, physical eduction and experiment related courses. Also, 90% of the basic and major courses of our department are operated in English, which meet the requirement of the development on English-teaching project.

In terms of the internationalized engineering practice education, utilization of the local advantages and resources contribute to the application of internationalized engineering practice education to the practice education. Also, it helps to the exploration and establishment of a workable and effective education mode with internationalized engineering practice background. Uniquenesses of overseas social practice, design of internationalized courses and internationalized final year project were formed which allow students to broaden their view, be familiar with the international regulations and improve their communinication ability. Hence, their view of international engineering project was built gradually.

For the internationalized joint training, the advantages of development on English-taught major play a key role in joint training program with prestigious university. Especially, more and more students can be benefited from the international exchange program and summer holiday researches program which create an automasphere of internationalized education. Now, more and more students are able to participate in the exchange program (overseas social practices are excepted) during their studies which contribute to a cover rate up to 35%. Besides, based on the development on English-taught major, we now spend no efforts to develop ways tailored to overseas students' education. To become a well-known university globally, almost 20 overseas students are admitted by our department every yaer, nearly 4 times than before.

VI. Conclusions

The implementation of "The Belt and Road " strategy has provided great opportunities and challenges for China's infrastructure construction to go abroad. The civil engineering major of South China University of Technology (SCUT) firmly grasps the opportunity, takes the lead in setting up the civil engineering English-Taught major in China, and has taken a solid step in the training of international civil

engineering talents. We deeply realize that the development of English-Taught major is not only an education and teaching reform, but also play an important role with its radiation and driving effect. Taking this work as a starting point, we can gradually cultivate the soil of internationalization, internationalizing internally and externally, and make the internationalization work of schools and colleges normally and sustainablly. Finally, promote the internationalization process of the work of schools and colleges.

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Comparative Study on the Civil Engineering Education in Australia and China

Y.X. Zhang
School of Computing, Engineering and Mathematics
Western Sydney University, NSW, 2751, Australia
Email:sarah.zhang@westernsydney.edu.au

Lei Zhang
School of Architecture and Civil Engineering,
Xi'an University of Science and Technology (XUST),
Xi'an, 710054, China
Email: leizhang0730@126.com

Abstract- In this paper, teaching method and practice on civil engineering program in Australia and China are illustrated and compared via several typical and fundamental courses. The methods for curriculum and program design, teaching methods and assessment methods in the two education systems are compared. These comparisons provide illustrations that the civil engineering education programs in Australia provide training to the future engineers on knowledge, application capacity of knowledge and professional skills, while the civil engineering education in China focus on systematic and detailed learning of knowledge and analytical capability. The engineering education mode in Australia could provide a valuable reference for the recently proposed Coherent-Collaborative-Interdisciplinary Innovation (CCII) engineering education reform in China.

Keywords: Assessment methods; Civil engineering; Coherent-Collaborative-Interdisciplinary Innovation; Curriculum design; Teaching methods.

I. INTRODUCTION

Engineering education plays an important role in higher education, and it provides a driving force and intellectual support for economic development and social progress. Engineering education has a very long history in China, and it is well known that engineering education in China has a strong focus on training of students on systematic and detailed learning of knowledge and analytical capability, but lack of training of application ability of knowledge and professional skills. In order to proactively respond to the new round of scientific and technological revolution and industrial transformation and to support a series of national strategies such as service innovation-driven development in China 2025, in February 2017 the Chinese Ministry of Education proposed the Coherent-Collaborative-Interdisciplinary Innovation (CCII) [1] aiming to fully explore a new and more effective engineering education mode. Different from the traditional engineering education focusing on the training on knowledge only, the CCII aims to educate high quality talents with strong practical application ability and innovation ability with strong international competitiveness capability.

The higher education sector has been well developed in Australia which has been one of the largest business sectors. The engineering education of Australia has attracted a large number of overseas students including from China. In this paper, the teaching method and practice on civil engineering program in Australia and China are illustrated and compared via several typical and fundamental courses. The methods for curriculum and program design, teaching methods and assessment methods in the two education systems are compared. The engineering education mode in Australia is found to be able to provide a valuable reference for the recently proposed CCII engineering education mode in China.

II. CURRICULUM DESIGN OF CIVIL ENGINEREING PROGRAMS

In Australia, it is essential for a university to have the engineering programs accredited by Engineers Australia (EA) to make the program competitive. It should be noted that EA is also the organization in Australia to do professional evaluation for Engineers. EA is one of the member of the Washington treaty, and thus degree from the EA accredited engineering programs is acknowledged not in Australia, but also in other global Washington treaty member countries such as United States, the United Kingdom, Canada, Ireland, and New Zealand [2]. EA defines the graduate attributes for engineering programs, and the graduate attributes defined by each university are usually aligned with those defined by EA. When designing the civil engineering programs/curriculums, the program learning outcomes need to meet the civil engineering overall learning outcomes defined by EA, while the learning outcomes of each course under the program should be able to contribute to the overall learning outcomes of the program.

Take the civil engineering program at UNSW Canberra as an example where the first author was the civil engineering program coordinator for two years in 2017 and 2018. The mission of the Bachelor of Engineering (Honors) Civil Engineering Program at UNSW Canberra is to inspire and educate future engineers in knowledge, skills, professional awareness and insight that are essential to the professional practice and research in civil engineering. The program learning outcome include three components, i.e. A) knowledge and skill base; B)

engineering application ability, and C) professional and personal attributes. The detailed learning outcome under each of these three components are listed in Table 1. As the civil engineering program coordinator, the first author did a mapping between the course learning outcomes against the program learning outcomes in 2018 for further modification and development of the program. It was found that there was a fine decomposition of the course learning outcome for all the civil engineering courses which contributed well to the overall program learning outcomes. Using a point system with the maximum point of 3 denoting strong matching between the course learning outcome and program learning outcome, and 0 denoting no matching, the sum of the point for the component A, B and C program learning outcome contributed from the all courses is 150,162 and 90 respectively. This distribution of the sum points across the three components shows that engineering education in Australia emphases the training of all the three components. The first author was also involved in the mapping for other engineering programs at UNSW Canberra such as Aeronautical and Mechanical Engineering and similar conclusion was drawn from this activity. This is very typical and representative in the engineering program of the Australian universities. This engineering education system trains the students not only the knowledge but also on the application ability of knowledge in engineering problem and the professional and personal attributes, which are essential for a professional engineer. As a result, the students are supposed to be well prepared and ready for the engineering profession and employment as an engineers.

In Chinese engineering education system, when designing a course, each course has its own individual teaching objectives and learning outcome. However, there is a lacking of a detailed decomposition and systematic matching of the course learning outcomes to the overall learning outcomes of the program [3].

III. TEACHING METHODS

A. Student-centered versus lecturer-centered teaching

In Australian engineering education system, student-centered method has been the most common used teaching method, which has been employed in most of the universities. In some universities/schools, for example in School of Engineering and Information Technology at UNSW Canberra, flipped teaching model, which is a very much student-centered leaning/teaching method, has been tried as a pilot and innovative teaching method in some selected courses. While in China, the traditional lecturer-centered teaching has still been the most dominating teaching method which is widely used in most Chinese universities. Lecturers play a dominate role in the class, and the lecturers will present the lectures, explain the knowledge in very much details including the derivation of the formulas and then work on the worked examples to illustrate the problem solving in great details. There are no or few tutorial classes with little or no labs in the lecturer-centered teaching.

TABLE 1: LEARNING OUTCOME OF CIVIL ENGINEERING PROGRAM AT UNSW CANBERRA

Component	**Detailed learning outcome**
A. Knowledge and Skill Base	A-1: Ability to apply knowledge of science and engineering for the solution of civil engineering problems.
B.Engineering Application Ability	B-1:Ability to communicate professionally with engineers and effectively with the community at large.
	B-2: Possess in-depth technical competence in civil engineering and sustainable infrastructure development.
	B-3: Ability to employ engineering knowledge and methods to identify problems, formulate and conduct independent research and propose solution for civil engineering problems.
	B-4: Ability to employ engineering knowledge, skills, and modern tools to design a system, component, or process for problems related to civil engineering and sustainable infrastructure development and operation.
	B-5: Ability to function effectively as an individual, and in multi-disciplinary and/or multi-cultural teams, with the capacity to be a leader as well as an effective team member, understand the fundamental principles of civil engineering project management.
C.Professional and Personal Attributes	C-1: Understanding of the social, cultural, global and environmental responsibilities of the professional civil engineer.
	C-2: Understanding of the needs and principles of sustainable infrastructure design and development, awareness of the impacts of civil engineering solutions in both societal and environmental context.
	C-3: Understanding of professional and ethical responsibilities, recognizing their importance in civil engineering practice and commitment to them.
	C-4: Expectation of the need to undertake lifelong learning, ability to acquire knowledge for continuous professional development in civil engineering or pursue graduate study and recognize its importance.

While in student-centered teaching, the students play a dominate role in the class and the lecturer will present the general theory and concept and worked examples rather than every knowledge point [4]. The students will have more chance to participate in the class by discussions, working on problems and do hand-on work in labs. There are lectures but also tutorial classes and lab classes. In the flipped teaching mode, the lectures are significantly reduced with even no formal lectures while there are more discussions and groups works in tutorials. The lectures will explain and clarify the theory and concept when the students encounter problems when they solve the problems.

B. Project-based teaching/learning method

In teaching engineering courses in Australia, project-based teaching has been widely used and this could provide students with great opportunities to learn from engineering projects. Although this could be challenging, it has received overwhelming responses from the students, and the students usually found the projects interesting as they are direct application of the knowledge. For example, in the teaching of Engineering Mechanics offered at UNSW Canberra, which was a first-year fundamental course for all engineer programs (the first author was the course coordinator for this course in 2018), students worked in groups to design/analyze/build/test a truss bridge, which was their first engineering project. In this project-based learning, the students used the knowledge on truss analysis they leant from the course to design the truss bridge made of balsa wood and certain specific requirements in geometry and application need to be satisfied for the design. The winner design is (i) the structure that has the highest failure load to weight ratio; or/and (ii) the structure whose failure load is the closest to the predicted failure load from structural analysis. Through this project, the students enhanced deep understanding on knowledge and applied the knowledge to a design of a real engineering project. In the meanwhile, the students also developed team working and collaboration skills, and communication and technical writing skills, which are all important skills for an engineer. profession. This project has been a flagship project for engineering programs at UNSW Canberra and the building and testing were open to the general public and it has received lot of interest.

In China, the teaching of the Engineering Mechanics courses focus more on the delivering of methods, theories, concepts and solving the problems mostly from the textbook. There are a small or no proportion of this type of engineering project where the students can use the knowledge directly to design and test an engineering project. There has been a similar type of project in China but it has been run in the format of structural design competition at the regional or national level, and only some selected senior undergraduate students have the chance to participate in this project.

IV.ASSESSMENT METHODS

Effective assessments provide critical levers for student learning. According to Isaacs [5] many students treated assessment as central to their academic activities at university, and assessment could and did play an important role in their learning. Gibbs [6] stated that assessment was the most powerful lever that lecturers had at their disposal to influence the way that the students responded to courses and behaved as learners. The assessment methods and assessment tasks are most essential for the course design, which can impact the students' learning and course learning outcomes significantly. The assessments need to be designed to align with the expected learning outcomes.

The assessment methods for engineering courses adopted in Australia and China are quite different. In the engineering courses in Australia, almost every course has a comprehensive structure for assessing, which include multiple and mixed assessment tasks. Quizzes and final exam are based on individual efforts and these could encourage independent learning. Group-based labs and reports will encourage students to learn from peers and collaborative working skills. Progressive assessments have been generally adopted with assessments held progressively during the whole learning period rather than only in the final exam period. The answers to the assessments are often broad and divergent, which sometimes did not have a specific solution especially for labs and design-based assessments. This is good for stimulating students' innovation and potential.

In China, final exam has been the only one assessments in most of the engineering course for many years. In recent years the progressive assessment method has also been adopted, but the final exam still takes a very high weight. There are assignments (homework) after each lecture. The assignments are marked but usually taking no or a very little weight toward the final mark of the course. The assignments from Chinese engineering education system are often of single format, i.e. problem-based assessment, and the students need to use the knowledge to solve a large amount of problems to become very skilled in solving problems to well prepare for the exam. The assessments in Chinese higher education has a clear purpose to help student to understand and consolidate the knowledge, and to get skilled in

solving the problems, which usually have a unique and specific answer. The students could get very skilled and experience in solving problems but there is a lack of training of problem identification, and critical and creative thinking. In this pattern of assessments, many students lose interest in learning.

To show a comparison of the assessment methods used in the two systems, we take the course of Engineering Mechanics in UNSW Canberra as an example. This course is similar to the course of Theoretical Mechanics in XUST (the second author has been engaging in this course). The specific assessment tasks in both the two institutions are shown in Table 2.

As shown in Table 2, UNSW Canberra has various and mixed assessments. In addition to the two mid-term quizzes and the final exam, there are also lab reports (15%) and hand-in tutorial assessment which takes a weight of 18%. The final exam accounts for 50% of the total score. In the course offered in XUST the homework only takes 10%, with 20% for the one midterm exam and the final exam has a larger weight of 70%. It should also be noted that in UNSW Canberra, if the student fails the exam, students can only earn credit by repeating the course which will incur double payment. While in XUST, the student has the opportunity to sit for a supplementary exam. Even if a student fails the supplementary exam, she/he will have another chance to sit for the exam by paying little. Comparing with students' performance and attendance in class in both UNSW Canberra and in XUST, it was found that the students in XUST were less serious in studying than those in UNSW Canberra. It is believed that the supplementary exam policy may have led to the difference in learning efforts.

TABLE 2. ASSESSMENT TAKS AND WEIGHT

Engineering Mechanics	**Assessment tasks**	**Weight**	**Whether to allow make-up exam**
UNSW Canberra	Six hand-in assessments	18%	No
	Two Quizzes	17%	
	One Lab report	15%	
	Final exam	50%	
XUST	Homework and attendance	10%	Yes (two chances)
	One midterm exam	20%	
	Final exam	70%	

V. CONCLUSION

The teaching method and practice in civil engineering education in Australia and China are illustrated and compared via several typical and fundamental courses for civil engineering offered in UNSW Canberra and XUST. Via the comparison in curriculum and program design method, teaching methods and assessment methods in the two education systems, it is found that the civil engineering education programs in Australia provide training to the future engineers on knowledge, application capacity of knowledge and professional skills, such as collaborative and team work skills and professional communication skills. Australian engineering education is student-centered with various and mixed assessment tasks, which could inspire the students' interest and cultivate creative and innovative ideas.

Due to the influence of social environment, national conditions and traditional educational concepts, higher education in China is different from that in Australia. The civil engineering education in China focus on systematic and detailed learning of knowledge and analytical capability, but lack of training of application ability of knowledge and professional skills. Although Chinese education is more systematic and profound in imparting basic knowledge, such education mode and management system has its own limitation in cultivation of students' independent thinking and innovation ability. As a result, Chinese students may have excellent academic performance in university, but they often find themselves lacking of the professional skills and training and take a long period to get adapted to the work after graduation.

The recently proposed CCII engineering education mode in China is an important reform for the Chinese higher education. China has been exploring more effective teaching with a change from the traditional lecturer-centered method to student-centered method. There has been a reform on the curriculum to emphasize the engineering application skills and practice which can stimulate students' initiative in learning, improve students' practical ability, independent thinking and problem solving ability. The engineering education mode in Australia could provide a valuable reference for the CCII.

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Understanding the General Framework for Teaching Semantics and Syntaxes of Visual Languages to Computer Education Students Based on a Notion of Abstract Visual Syntax Graphs.

Eze Nicholas Ude
Department of Computer and Robotics Education, University of Nigeria.

Aniobi Samuel Onyekozulu
Department of Computer and Robotic Education University of Nigeria.

Abstract:

Objectives/Motivation*: The central problem of this study was that most teachers finds it practically impossible to prove properties of visual languages; as well as differentiate visual languages from other instructive counters of visual languages like Visual Basic etc as a result a lack of good framework to teach the semantics specification of different visual languages.*

Methods/Statistical Analysis: *This study therefore proposed a general framework which defined the abstract syntaxes and semantics of three selected notable visual languages with the aim of making a comparisons of their syntaxes and semantics to address teacher's confusion with other instructive counter example for visual programming languages like Visual Basic, Visual C#, Visual J#, etc which are under Microsoft Visual Studio and not visual languages.*

Findings*: The framework adopted in this study allows the teacher both logical and denotational approach to understand and improve in teaching visual semantics and their properties, as well as improve their formal understanding about other instructive counter example for visual programming languages.*

Novelty*: The use of a notion of abstract visual syntax graph to explain the semantics of VL for proper understanding makes this work unique.*

Keywords: *Euler Circle, Syntax, Semantics, Show and Tell, Teachers, VEX, Visual Programming Languages.*

Introduction

Teachers need to understand the meaning and general framework of the semantics and syntaxes of visual languages and that of other instructive counter example for visual languages like Visual Basic, Visual C#, Visual J#, etc for its effective use in classroom teaching and learning. This is because teachers often confuse visual languages with Visual Basic, Visual C#, Visual J#, etc for which the former are procedural programming languages and the latter are just its programming environment and not visual languages, [1]. They are not graphical, rather they are textual, [2], and they fall under Microsoft Visual Studio, [3] which are integrated development environment (IDE) used to develop computer programs. In other words, it supports over 36 different programming languages and allows the code editor and debugger to support nearly any programming language, provided a language specific service exists.

To properly understand their distinctions, Microsoft Visual Studio is one that provides the Visual Programming environments which provides graphical or iconic elements which can be manipulated by users in an interactive way according to some specific spatial grammar for program construction, [4]. Meaning, it only allows environment for programming with visual expressions, spatial arrangements of text and graphic symbols used either as elements of syntax or secondary notation. Many VPLs notations (as in *dataflow* or *diagrammatic programming*) are based on the idea of "boxes and arrows", where boxes or other screen objects are treated as entities, connected by arrows, lines or arcs which represent relations, see [5, 6]. These entities are being manipulated by users through the graphical environment of the Microsoft visual studio. One example of such visual programming environments is Visual Basic, (VB).

Visual Basic is an enhancement of BASIC which has visual object-oriented components features and codes that enables for procedural structures of sequence, iteration and selections, [7, 8]. In other words, it enables the display of visual languages

with the use of visual objects like a button which has encapsulated properties and event procedures, [9, 10]. VB has public and private procedures like other object oriented programming languages for which visual languages lacks which makes them different from each other, [11, 12, 13, 14, 1]. VB though may contain object oriented component, it is not hemispheric independent like visual languages, [15].

However, visual language on the other hand, explains an inherent visual expression for which there is no obvious textual equivalent but only allows users to create programs through graphical means, [16]. VLs are classified into icon-based languages, form-based languages, and diagram languages depending upon the type and extent of visual expression used, [5, 6 17]. It is on the bases of these classifications that this work is tailored, to form a general underlying framework for teaching visual languages to college students. This is because there is no general framework available which could be used for the formal specification for teaching of visual languages. A possible reason why this does not happen might be that some of the components that are necessary for a semantics framework are missing. Taking denotational semantics as an example, we observe that – at least as far as visual *programming* languages are concerned – the necessary concepts of semantic function and semantic domain can be used as in the textual case. Again, *abstract syntax*, cannot also be taken for visual languages, and there is no equivalent notion for visual languages yet.

However, understanding these frameworks requires a different mindset from what is available [18]. For example, the teacher must have a precise definition of the semantics and syntaxes of visual programming languages to ease a thorough understanding of the distinction between the visual programming environments like *Visual Basic* [19, 20]. This understanding when acquired can help the teacher to appraise a visual programming language and make comparison with visual Basic. Secondly, understanding just a precise specification of semantics of a visual language will make it easier and simpler for the teacher because it is just a few steps towards an implementation. For example, it will make the teacher to possibly translate almost verbatim most denotational language's semantics into functional languages, hence making the interpreter for the language immediately available, [20]. Thirdly, a good understanding of a precise semantics of a visual language will make it easier for the teachers to be able to prove various properties of languages and integrate them correctly into other environments as in heterogeneous or multi-paradigm languages, [19]. Such understanding may have a positive influence on the productivity of students in computer programming languages [21].

To achieve this understanding, we have based our study on three selected notable VPL's; VEX, Show and Tell and Euler circle to ascertain the true definition of their semantics and syntaxes and the general framework underlying their teaching in colleges. This is because a large variety of visual languages exists of which only few are equipped with proper syntax definition, [22]. So in the sequel we will first introduce some related work on the above subject matter. Concept of abstract visual syntax will be treated in Section 2 before we demonstrate the specification of logical and denotational semantics in Sections 3 and 4 by two simple examples. In Section 5 we show the 3 notable visual programming languages and deal with the comparison of their syntaxes and semantics by the presented approach. Section 6 comments on related work, and Section 7 presents some conclusions.

2. Related Work

2.1 Syntax of Visual Languages

There has been quite a lot of work concerning the syntax of visual languages, for an overview, see [23]. However, all these formalisms are concerned with the specification of concrete syntax and address the related aspects of parsing and syntax directed editors. Only few papers deal with abstract visual syntax. In the works of [24, 25, 26], the authors recommend the separation of abstract syntax from concrete syntax. However, this is only partially achieved by those approaches, since they require a one-to-one correspondence between concrete and abstract syntax, and thus abstract syntax is intrinsically coupled very closely to concrete syntax. Also, that work is only concerned with translation of visual languages; aspects of semantics definitions are not discussed. More on abstract visual syntax as used in this paper can be found in the works of [27].

2.2 Semantics of Visual Languages

Besides semantics definitions for specific languages, [28] had it that there has been not much done about semantics of visual languages in general. [29] take an algebraic view of modeling pictures. Their goal is to get a formal basis for visual reasoning by axiomatic characterizations of what can be seen in a picture. The work of [30] is centered on the formal understanding of and reasoning with images. Both approaches are based on concrete visual syntax and are not targeted at the semantics specification of visual *programming* languages.

The term "semantics" is sometimes used with a different meaning, for example, according to [16], it means a set of pictures satisfying a given specification, that is, the semantics is a visual language itself and not a mathematical domain describing the computations performed by a visual language.

2.3 Graph Representation

Using graphs to describe pictures is a common and wide-spread approach. This is because, sentences of visual languages (VL's) has often been treated as assemblies of graphical and pictorial objects with some spatial relationships between them which provides information about the syntax and semantics of the visual sentences in a more succinct form to students learning computer programming, [22].

Graph grammars are a natural means for defining the concrete and the abstract syntax of VLs. In other words, they are used to generate syntax directed VL editors which supports free editing and parsing of their underlying graph structures. General models that apply to a broad range of visual languages are few. Examples are seen in theory of graph grammars and the Harel's higraphs [31]. Higraphs are a kind of amalgam of hierarchical graphs and Euler/Venn diagrams. Higraphs have a concise formal semantics, and by modeling a visual language *VL* as a higraph, the semantics of *VL* is implicitly defined. Higraphs provide a perfect representation for those visual languages that exactly fit that model. However, since higraphs have a fixed structure, their applicability is restricted, and only a certain class of visual languages can be expressed in terms of them. Hence, although quite many applications can, in principle, be described as higraphs, several of them require changes of their concrete syntax, and some languages cannot be described at all. Moreover, the lack of an inductive view of higraphs makes denotational specifications difficult, if not impossible.

Graph grammars, on the other hand, provide a fairly general model of visual languages. Graph grammars are very powerful, and they have been extensively used to describe graph transformations. Graph grammars enjoy a large body of theoretical results, and they also provide, in a certain sense, an inductive view of graphs. So why should we need yet another graph model? A major difficulty with graph grammars is that they consider the graphs they operate on as global variables that can be updated destructively. This means that changes performed by grammar rules are implicitly propagated, and thus a declarative treatment of graphs is prohibited. Things are complicated by the fact that the semantics of graph grammars themselves is rather complex due to advanced embedding rules and nondeterminism. In contrast, the inductive graph view presented in this paper is quite simple, and it treats graphs as explicit parameters of transformations.

2.4 Abstract Visual Syntax Graph and Graph Grammar

The abstract visual syntax of a VL represents the internal (logical) structure of the diagram according to its visual language. In other words, its nodes and edges must correspond to its language formations. For example, in figure 1 below, 1b is an appropriate ASG for the ER diagram of figure 1a which

contains everything required to interpret the diagram. See figure 1 for the internal representation of a diagram.

Insert Figure 1 here

On the other hand, a graph grammar defines which graphs are correct or not and also specifies how such grammars are to be formed, [32]. As seen in figure 2, when such a grammar for connecting ER abstract syntax graph are joined together with a grammar for the allowed spatial relations graph, it forms a complete syntax definition for the visual language of ER diagrams. Graph grammar uses more of textual languages. For example, see figure 2 below for the diagram for correct ER abstract syntax graph grammar.

Insert Figure 2 here

A textual language L is a set of strings over an alphabet A, that is, $L \subseteq A^*$. The symbols of any sentence (or word) $w \in L$ are only related to each other by a linear ordering. In contrast, a sentence (or diagram or picture) p of a visual language VL over an alphabet A consists of a set of symbols of A that are, in general, related by several relationships $\{r1, \ldots, rn\} = R$. Thus we can say that a picture p is given by a pair (s, r) where $s \subseteq A$ is the set of symbols of the picture and $r \subseteq s \times R \times s$ gives the relationships that hold in p.1. In other words, p is nothing but a directed graph with edge labels drawn from R, and a visual language is simply a set of such graphs. Usually, languages contain a certain structure, that is, there are precise rules defining which symbols can occur in which contexts and, regarding visual languages, which symbols may take part in which relationships. This structure is recognized and enforced during syntax analysis, and it can be assumed when defining semantics. Therefore, semantics definitions are often based on so-called *abstract syntax* which defines a language on a more abstract level with fewer constraints than on the concrete level. This means that a description of concrete syntax must include every detail about the language whereas the abstract syntax can safely ignore all aspects that are not needed within the semantics definition. A precise definition of abstract syntax does not exist, and it would not make much sense because there are different levels of "abstractness" that can be dealt with. One reason for abstract syntax not really having found its way into visual languages might be that, as we believe, abstract visual syntax must be "more abstract" than in the textual case to be helpful. We explain this by a simple example. Consider the following (textual) grammar describing part of a concrete syntax for expressions.

expr::= *n-expr* | *b-expr* | *if-expr*

n-expr::= *term* | *n-expr* + *term*

term::= *factor* | *term* * *factor*

factor::= *id* | (*n-expr*)

b-expr::= *id* | *b-expr* ∨ *b-expr* | …

if-expr::= **if** *b-expr* **then** *expr* **else** *expr*

A corresponding abstract syntax would ignore many details, such as the choice of key words, grammar rules for defining associativity of operators, or rules restricting the typing of operations, [20]:

expr::= *id* | *expr op expr* | **if** (*expr*, *expr*, *expr*)

op ::= + | * | ∧ | ∨ | …

This grammar is much more concise. It does not introduce non terminals for expressions of different types, and it also ignores associativity of operators. (Omitting the key words from the conditional does not make the grammar essentially simpler in this example.) Further operations on sentences of the language can rely on syntax being already checked by a parser and can thus work with the simpler abstract syntax.

In a similar way, the abstract syntax of visual languages need not be concerned with all the details that a concrete syntax specification has to care about, [27]. This means we can abstract from the choice of icons or symbols (comparable to the choice of key words in the textual case) and from geometric details such as size and position of objects (at least up to topological equivalence, that is, as long as relevant relationships between objects are not affected). We can also ignore associativities used to resolve ambiguous situations during parsing much like in the textual example. Moreover, typings of relationships that restrict relationships to specific subsets of symbols can be omitted. This corresponds to grouping operations, such as + or □, under one nonterminal.

But we can do even more – and this is the point where abstract visual syntax gets more abstract than in the textual case: the above abstract syntax for expressions is still given by a grammar and thus retains some structural information about the language. This is absolutely adequate since the description is very simple and can be easily used when defining, for example, an interpreter for expressions. However, to do so for a visual language requires, in most cases, some effort in the consideration of context information which unnecessarily complicates definitions of transformations. Therefore, we suggest to forget about this structural information, too, and to consider a picture just as a directed, labeled multi-graph where the nodes represent objects and the edges represent relationships between objects. A class of graphs is then just given by two types defining node and edge labels, that is, the types of objects and relationships in the abstractly represented visual language.

Definition 1. A *directed labeled multi-graph of type* (□, □) is a quintuple $G = (V, E, □, □, □)$ consisting of a set of nodes V and a set of edges E where □□: E □□V □□V is a total mapping defining for each edge the nodes it connects. The mappings □□: V □□□□and □□: E □□□□define the node and edge labels.

VG and EG denote the set of nodes and edges of G. The successors of a node are denoted by $succG(v)$, which is defined by $succG(v) = \{w \in VG \mid \exists e \in EG: □(e) = (v, w)\}$. Likewise, $predG(v)$ denotes v's predecessors. Whenever G is clear from the context, we also might simply use V, E, *succ*, and *pred*. We also sometimes use a shorthand for denoting nodes and edges together with their labels: we denote a node (or edge) x with $□(x) = l$ (respectively, $□(x) = l$) simply by $x{:}l$.

The label types □□and □□might be just sets of symbols, or they can be complex structures to enable the labeling with terms, semantic values, or even graphs. The set of all graphs of type (□, □) is denoted by □(□, □). In the sequel we will look at visual languages on this very abstract level, that is, the abstract syntax of a visual language is specified as a set of graphs of a specific type.

Definition 2. A *visual language of type* (□, □) is a set of graphs VL □□□(□, □).

How does this view relate to the well-established grammatical approach to syntax? Clearly, the syntax of languages can be conveniently specified by grammars. Grammars provide a way to generate all sentences of the language and, given a suitable parsing algorithm, allow testing whether a sentence is a member of the language (possibly giving a proof for this by constructing a parse tree for reconstructing the sentence). Concerning abstract syntax, however, grammars are usually not used for parsing; their purpose is just to offer an inductive or decompositional view of language that facilitates semantics definitions, especially, denotational semantics or structured operational semantics. As demonstrated by [27], we can actually have a (de)compositional/recursive view of graphs without resorting to grammars. So we can achieve a highly abstract comprehension of pictures together with an inductive view of graphs that facilitates, say, denotational semantics definitions. On the other hand, there are visual languages whose semantics are best described in a logical fashion. In that case a global, set-theoretic view of language is needed, which is just given by abstract visual syntax (and

which might be obscured when using grammatical formalisms).

As in the textual case the choice of abstract syntax for a visual language is by no means unique. Usually, one has to trade similarity to the original notation for simplicity of the semantics definition. We will illustrate this point further in Section 4. The use of abstract syntax is not restricted to the definition of language semantics, but it can be also used as a basis for transformations between different languages or for mapping between different representations of the same language. This is illustrated in more detail by [27]. Accidentally, the abstract syntax graphs for the examples used in this paper are all acyclic. This is by no means essential for the presented formalism. Examples for visual languages that have cyclic abstract, syntax graphs are state diagrams or a particular representation of Turing machines.

2.5. Logical Semantics

In many cases, a logical specification of semantics views the syntactic elements simply as sets. For graphs, the node- and edge-set view is implicit in the definition. In Section 3.1 we define syntax and semantics of the well-known Euler diagrams, and in Section 3.2 we prove a visual rule for syllogistic reasoning and thus illustrate how to establish properties of a formalized visual language.

3. The three Notable Visual Languages

3.1 Euler Diagrams (Circle)

The language of Euler diagrams as described by [5, 6], contains four kinds of basic pictures expressing logical statements:

Insert Figure 3

Ambiguities of Euler diagrams and semantic problems arising from these are discussed in detail by [5]. Our aim is not arguing in favor of or against using Euler diagrams for reasoning. However, as a matter of fact, Euler diagrams are a wide-spread visual notation, and in order to discuss the notation and compare it with others, it should be understood in the first place. This is what abstract visual syntax and the semantic formalism can accomplish.

The concrete syntax of Euler diagrams comprises circles and string-labels together with the relationships *inside*, *intersects*, and *disjoint*. Labels have two purposes: first, they provide references to set symbols in pictures to be used in explanations, discussions, etc. Second, their position distinguishes two different set relationships for intersecting circles. In the abstract syntax we can therefore omit labels and replace the *intersects*-relationship by two edge labels identifying the third and fourth situations, namely, *p-intersects* and *nic*. The names result from the following observations: in order to give a formal semantics to Euler diagrams one has to answer the following questions (among others):

(1) Does the third situation also say: "Some *B* is not *A*" ? Yes, Euler also specifies that

"Some *A* is not *B*" (and "Some *B* is *A*"). Thus we know:

(a) *A* □□*B* □□□,

(b) *A* - *B* □□□, and

(c) *B* - *A* □□□.

So this situation describes what we call *proper intersection*, that is, we say *A p-intersects B*.

(2) Is the relative position of labels irrelevant, that is, does the last example also say "Some *B* is not *A*" ? This would be reasonable, and although Euler gives as one possible instance an example where *B* is completely inside (that is, properly included in) *A*, he himself uses the notation in a symmetric way later on in his letters. Accordingly, we ignore relative positions of labels. So this relationship describes that both differences are non-empty which expresses nothing but the fact that two sets are not

comparable with respect to inclusion; we call this relationship *n*ot *i*nclusion-*c*omparable.

Except *inside*, all relationships are symmetric. We depict a symmetric relationship by an undirected edge which is represented in a directed graph by two directed edges in both directions. So the abstract syntax graphs for the Euler diagrams of Figure 1 look like:

Insert Figure 4

The semantics is defined for a diagram relative to a *universe* of objects *U*. An interpretation is a mapping from the set of circles in the diagram, that is, nodes of the graph, to subsets of *U*, that is, $f : V \to 2^U$. Now the semantics can be easily defined:

$S[[(V, E)]]U = \{f \mid f : V \to 2^U \wedge \forall e \in E: valid(f, \sigma(e), \tau(e))\}$

Where

$$valid(f, (u, v), l) = \begin{cases} f(u) \subseteq f(v) & \text{if } l = inside \\ f(u) \cap f(v) = \emptyset & \text{if } l = disjoint \end{cases}$$

$$f(u) \cap f(v) \neq \emptyset \wedge f(u) - f(v) \neq \emptyset \wedge f(v) - f(u) \neq \emptyset \quad \text{if } l = p\text{-}intersects$$

$$f(u) - f(v) \neq \emptyset \wedge f(v) - f(u) \neq \emptyset \quad \text{if } l = nic$$

3.1.1 Soundness of Visual Reasoning Rules

Having a precise definition of what Euler diagrams mean it is quite easy to check the visual rules for syllogistic reasoning. Euler gives textual versions of such rules and explains them by pictures. One example is:

All *A* is *B* Some *C* is *A*

Some *C* is *B*

Although this sounds very intuitive, this rule is formally *not* correct since "Some *C* is *B*" does only hold if $C - B \neq \emptyset$. But this cannot be concluded from the premises; *C* might well be included in *B*. Actually, Euler is aware of this fact and gives pictures illustrating both cases. The point is that there is no formal correspondence between propositions and pictures (since there is no formal semantics). Now the correct rule is:

All *A* is *B* Some *C* is *A*

All *C* is *B* or Some *C* is *B,*

or equivalently in visual terms:

The semantics definition ensures for each valid interpretation the following properties:

(1) $A \neq \emptyset B$

(2) $A \neq \emptyset C \neq \emptyset$

(3) $A - C \neq \emptyset$

(4) $C - A \neq \emptyset$

First we observe from 3 and 4 that neither *A* nor *C* is empty. By (1) it also follows that *B* is not empty. For the intersection and difference of two non-empty sets we know:

(i) $X \neq \emptyset Y \neq \emptyset \wedge \forall Z \neq \emptyset: Z \neq \emptyset X \neq \emptyset Z \neq \emptyset Y$

(ii) $X - Y \neq \emptyset \wedge \forall Z \neq \emptyset: Z \neq \emptyset X \neq \emptyset Z \neq \emptyset Y = \emptyset$

Next we translate the conclusion of the rule into logical terms. That is, have to show that the following is true:

(*C* □□*B* □□□□□□*C* - *B* □□□□□□*B* - *C* □□□) □□*C* □□*B*

We can simplify this term: first, since *C* □□*B* implies *C* □□*B* □□□□(because *C* is not empty), we know that

C □□*B* □□□□□□*C* □□*B*□*C* □□*B* □□□,

and second, *C* - *B* □□□□□□*C* □□*B* is always true which can be easily checked by considering all possibilities with respect to the intersection of *C* and *B*. Thus it remains to be shown:

C □□*B* □□□□□□(*B* - *C* □□□□□□*C* □□*B*)

We can prove both parts separately. First, from (2) and (i) we infer □*D* □□□:

(5) *D* □□*A* and

(6) *D* □□*C*

By transitivity it follows from (5) and (1) that *D* □□*B*, and this together with (6) and (i) implies *C* □□*B* □□□. Second, we obtain from (3) and (ii) that □*D* □□□:

(7) *D* □□*A* and

(8) *D* □□*C* = □

By transitivity it follows from (7) and (1) that *D* □□*B*, and this together with (8) and (ii) implies

B - *C* □□□. This means that *B* - *C* □□□□□□*C* □□*B* is also true.

3.1.2. Recursive Semantics

In contrast to the predicative view that was convenient in the previous section, many languages are defined inductively, and then a semantics definition is easiest to give when adopting that inductive view. We illustrate these ideas with the visual language VEX in the work of [33], which provides a visual notation for the lambda calculus. We chose VEX, since it is a rather small (but computationally complete) language and since any semantics can be easily verified by comparison with the classical lambda-calculus.

In Section 3.2 we explain VEX informally, followed in Section 3.2.1 by two alternative abstract syntax definitions. Sections 3.2.2 and 3.2.3 introduce an inductive/decompositional view of syntax graphs that is particularly needed for the definition of denotational semantics. Based on this, a semantics for VEX is then given.

3.2 VEX

VEX according to [33], is a purely visual language: each identifier is represented by an (empty) circle that is connected by a straight line to a so-called *root node*. A root node is again an empty circle with one or more straight lines touching it, leading to all identifiers with the same name. A root node might be internally tangent to another circle, it then represents a parameter of an abstraction, and otherwise it denotes a free variable. An abstraction has, in addition to its parameter circle, a body expression inside it. An application of two expressions is depicted by two externally tangent circles with an arrow at the tangent point. The head of the arrow lies inside the argument, and the tail of the arrow lies inside the abstraction to be applied. Application order can be controlled by labeling arrows with priority numbers which we will ignore for simplicity.

3.2.1 Choices of Abstract Syntax

The VEX concrete syntax consists of symbols like circles, lines, and arrows, and relationships like inside or touches. As already mentioned, there are quite different possibilities for the abstract syntax. In a first approach we can abstract from lines and arrows and replace them by corresponding relationships since lines simply link the use of a variable to its definition and arrows just indicate the application of one circle to another. This is reflected in the abstract syntax graph of a VEX expression by *def*-edges (that is, edges labeled with *def*) that lead

from variable uses to their definition and by *apply*-edges leading from the expression circles to be applied toward the argument circles. It remains to represent abstractions. An abstraction is given by a non-empty circle *c* where an (empty) circle *x* that is internally tangent to *c* represents *c*'s parameter and all other circles *e*1, …, *en* inside *c* define the abstraction body. In the abstract syntax we represent this information by a *par*-edge from *c* to *x* and by *body*-edges (*c*, *e*1), …, (*c*, *en*). Note that we do not need to distinguish abstraction nodes from variable nodes by an explicit label since the difference can always be told by looking at the incident edges – by this the abstract syntax is more similar to the concrete syntax. Therefore we do not use any node labels, and thus the abstract syntax for VEX is given by graphs of type (□, {*def*, *apply*, *par*, *body*}).

This representation is rather close to the spatial original and should therefore be easy to grasp. However, a DAG representing the lambda-expression in a rather traditional way might be better suited to study, for example, semantics of □-reduction.

Such a representation consists of application-, abstraction- and variable-nodes (with corresponding node labels: @, □,).1 An @-node has an outgoing *fun*-edge and an outgoing *arg*-edge that lead to the function to be applied and the argument, respectively. A □-node is connected by an outgoing *par*-edge to its parameter, an unlabeled node, and by an outgoing *body*edge to the node representing its body. Hence, this abstract syntax for VEX uses graphs of type

({@, □}, {*fun*, *arg*, *par*, *body*}).

At this point it is important to recall that the informally stated structural properties are not captured by abstract syntax graphs. This means that the graph shown below is also a graph of the above type although it is certainly not representing any VEX expression. For defining semantics we can safely assume structurally correct graphs be delivered, say, by a syntax analysis phase or an editor. The structural assumptions can then appear implicit in the semantics definition since we need only give semantics for structurally well-formed graphs, that is, syntactically correct pictures. Although the second representation offers advantages in treating certain aspects of semantics, it does only poorly reflect the visual structure of the VEX expression, and might thereby complicate the understanding of the original *visual* language. The decision of which representation to choose depends on what is done with the semantics definition: for just giving a meaning to VEX pictures, the first approach might be sufficient, however, when trying to prove, for example, soundness of □-reduction, or deriving an implementation, the second representation would probably be favored.

Next we would like to define the semantics on the basis of the abstract representations just given. We therefore need a structured way of accessing all the elements of a syntax graph. In particular, we need an inductive view of graphs that allows the step-by-step decomposition of graphs. We will address this issue in the next two subsections. The concepts presented there can also be used to map between different syntax representations.

3.2.2 An Inductive Graph Model

We can view a graph in the style of algebraic data types found in functional languages like ML or Haskell: a graph is either empty, or it is constructed by a graph *g* and a new node *v* together with edges from *v* to its successors in *g* and edges from its predecessors in *g* leading to *v*. This way we can construct graph expressions with a constant constructor *Empty* and a constructor *N* taking as arguments a triple (*pred-spec*, *node-spec*, *succ-spec*), called *node context*, and the graph *g* to be extended. Here, *node-spec* is a node identifier not already contained in *g* possibly followed by a label (for example, *d*:@) and *pred-spec* (*succ-spec*) denotes a list1 of predecessor (successor) nodes possibly extended by labels for the edges that come from (lead to) the nodes. For instance, [*d*›*fun*, *e*] denotes a list of two predecessor nodes *d* and *e* where the edge coming from *d* has label *fun* and the

edge coming from *e* has no label at all. Similarly, [*par*›*a*, *body*›*a*] denotes a single successor *a* that is reached via two differently labeled edges.

N ([], *d*:@, [*fun*›*b*, *arg*›*c*]) (*N* ([], *c*, []) (*N* ([], *b*:□, [*par*›*a*, *body*›*a*]) (*N* ([], *a*, []) *Empty*)))

Here *a*, *b*, *c*, and *d* are arbitrary, pairwise different node identifiers. In the sequel we make use of two abbreviations: (1) empty sequences can be omitted, and (2) a cascade of *N*-constructors is replaced by a single *N**-constructor. So the above term can be simplified to:

*N** (*d*:@, [*fun*›*b*, *arg*›*c*]) (*c*) (*b*:□, [*par*›*a*, *body*›*a*]) (*a*) *Empty*

Note that there are, in general, many different graph expressions denoting the same graph, for example, the above term denotes the same graph as:

*N** ([*d*›*fun*], *b*:□, [*par*›*a*, *body*›*a*]) (*d*:@, [*arg*›*c*]) (*c*) (*a*) *Empty*

The relationship between graph expressions and multi-graphs is formally defined as follows:

□(*Empty*) = (□, □, □, □, □)

□(*N* ([*p*1›*x*1, …, *pn*›*xn*], *v*:*l*, [*y*1›*s*1, …, *ym*›*sm*]) *g*) =

(*V* □□ {*v*}, *E* □□ {*e*1, …, *en*+*m*},

□□□□ {(*e*1, (*p*1, *v*)), …,(*en*, (*pn*, *v*)), (*en*+1, (*v*, *s*1)), …, (*en*+*m*, (*v*, *sm*))},

□□□□ {(*v*, *l*)},□□□□□ {(*e*1, *x*1), …, (*en*, *xn*), (*en*+1, *y*1), …, (*en*+*m*, *ym*)})

Where

(*V*, *E*, □, □, □) = □(*g*), {*e*1, …, *en*+*m*} □□ *E* = □, {*p*1, …, *pn*, *s*1, …, *sm*} □□ *V*, *and v* □□ *V*

Thus, multi-graphs can serve as a kind of normal form for graph expressions. The following result is important, since it guarantees that any graph can be viewed inductively:

Theorem 1. *Any directed labeled multi-graph can be represented by a graph expression.*

The proof is given in [7]. There we also define a formal semantics of graph types and graph constructors.

3.2.3 Pattern Matching on Graphs

The main use of graph constructors in the context of this paper is not to build new graphs but to take part in pattern matching on graphs. Especially useful for graphs is the concept of *active patterns* [34]: usually, matching a pattern like *N* (*p*, *v*:*l*, *s*) *g* to a graph expression binds the node context inserted last to *p*, *v*, *l*, *s* and the remaining graph to *g*. However, in order to move in a controlled way through the graph, it is necessary to match the context of a specific node. This is possible if *v* is already bound to the node to be matched. Then the context of *v* is bound to the remaining variables. For instance, matching the pattern *N* (*p*, *b*:*l*, *s*) *g* against either graph expression from the previous subsection results in the following bindings:

p □□ [*d*›*fun*], *l* □□□, *s* □□ [*par*›*a*, *body*›*a*], *g* □□ "*g-term*"

where *g-term* is an arbitrary representation of the matched graph without node *b* and its incident edges, for example,

"*g-term*" □□ *N** (*d*:@, [*arg*›*c*]) (*c*) (*a*) *Empty*)

Formally, graph pattern matching is defined on the basis of the represented multi-graphs. For a given node *v* assume *G* can be written as:

G = (*V*+{*v*}, *E*+{*e*1, …, *en*+*m*},

□+{(*e*1, (*p*1, *v*)), …,(*en*, (*pn*, *v*)), (*en*+1, (*v*, *s*1)), …, (*en*+*m*, (*v*, *sm*))},

□+{(*v*, *l*)},□□+{(*e*1, *x*1), …,(*en*, *xn*), (*en*+1, *y*1), …, (*en*+*m*, *ym*)})

where *S*+*T* denotes disjoint set union and where the disjoint union for *E* is chosen maximally, that is, there is no *e*' □□ *E* such that there exists (*e*', (*x*, *y*))

□□□□with $x=v$ or $y=v$. Then matching the pattern $N\,(p, v{:}l, s)\;g$ to G produces the bindings:

p □□[$p1{\rightarrow}x1$, …, $pn{\rightarrow}xn$], l □□lab, s □□[$y1{\rightarrow}s1$, …, $ym{\rightarrow}sm$], g □□(V, E, □, □, □)

This means that the meaning of pattern matching does not depend on the representation chosen by a particular graph expression. In other words, we have the freedom to choose graph expressions as we like; we make use of this later on in this paper when we apply semantics definitions to example graphs. Then we shall choose representations that make inductive decompositions of graphs simple so that we need neither transform graph expressions nor map them to the represented multi-graphs.

Patterns can be made more selective by adding labels that must be present or by replacing list variables by lists of a specific length. We can also ignore bindings by simply omitting the corresponding parts of the pattern, for example, we can match the abstraction node b binding the parameter/body node to p/e by using the pattern:

$N\,(b{:}\square, [par{\rightarrow}p, body{\rightarrow}e])\;g$

Actually, p and e will be bound to the same node, a. Since we did not specify anything for the predecessor list, no binding will be produced. If we wanted to ensure that the matched node has no predecessors we would have used the pattern $N\,([], b{:}\square, [par{\rightarrow}p, body{\rightarrow}e])\;g$ instead. This, however, fails to match our example graph.

Cascading patterns like $N^*\;c1\;c2\;\ldots\;cn\;g$ can be matched against a graph G as follows: let $g1$, …, gn be auxiliary variables to be bound to intermediate decomposed graphs. Now first, $N\,c1\;g1$ is matched against G, and the bindings produced by this match, especially the node bindings in $c1$ and the rest graph $g1$, are then used to match $N^*\;c2\ldots\;cn\;g$ against $g1$, that is, $N\,c2\;g2$ is matched against $g1$, $N\,c3\;g3$ is matched against $g2$, and so on, until $N\;cn\;gn$ is matched against gn-1. Then g is bound to gn. In this way, N^* patterns can actually be used to conveniently find paths (of fixed length) in the graph.

3.2.4 Denotational Semantics

Now we can define the denotational semantics of VEX. We map each syntax graph of a (syntactically correct) VEX expression into a value of a suitable domain ***D*** for the lambda-calculus (for example, Scott's construction D□□or Plotkin's graph model P□). Let ***d*** be a variable denoting values from ***D***. It is interesting to note that in contrast to the denotational semantics of the textual lambda-calculus we do not need any environment for passing around variable bindings; we can rather employ the VEX root nodes to carry semantic values. It would be also possible to map the abstract syntax to textual lambda-expression and to rely on semantics already defined for the lambda-calculus. However, this would mean one further intermediate representation and, as noted, a sligthly more complicated semantics definition with the need for an environment.

We define the semantics by moving in a controlled way through the abstract graph, that is, semantics are given with respect to specific node contexts in the graph, and in the recursive definitions for the semantics of, say, node v, the semantics function S' is applied to the contexts of v's successors. Hence, S' has two parameters: a graph and a node determining the context. Using the second proposal for abstract syntax we can distinguish the following cases: first, the semantics of a node carrying a semantic value is the value itself. (Such a value is assigned by the rule for abstractions.) Second, the meaning of an application node is given by applying the semantics of the node connected by the *fun*-edge, which is expected to be a function value, to the value denoted by the argument node. Finally, the semantics of an abstraction is defined to be a function value (□□denotes the semantic abstraction function) which maps any value ***d*** to the value denoted by the body of the abstraction when the parameter node is labeled ***d***. Note that in order to change the label of the parameter node p to ***d*** we have to decompose p from the graph and re-insert it

with the new label and the old context (that is, with predecessors *r* and no successors).

S'[[*v*, *N* (*v*:***d***) *g*]] = ***d***

S'[[*v*, *N* (*v*:@, [*fun*›*f*, *arg*›*a*]) *g*]] = *S*'[[*f*, *g*]] (*S*'[[*a*, *g*]])

S'[[*v*, *N** (*v*:□, [*par*›*p*, *body*›*b*]) (*r*, *p*) *g*]] =

□***d.****S*'[[*b*, *N* (*r*, *p*:***d***, []) *g*]]

Now the semantics of a graph *G* representing a VEX expression is given by applying *S*' to the root of *G*. *root*(*G*) = {*v* □□*VG* | *predG*(*v*) = []}

S[[*G*]] = *S*'[[*the*(*root*(*G*)), *G*]]

Here, the function *the* simply extracts the one element from a singleton set and is undefined otherwise: *the*({*x*}) = *x*.

We can use the denotational semantics to "compute" the meaning for particular VEX expressions. For convenience we repeat the abstract syntax representation with added node identifiers in Figure 6 to facilitate the understanding of the following derivation.

The graph (*G*1) is formally defined by the following expressions. The representations are chosen to make subsequent pattern matching easy and to have proper bindings for remaining graphs:

*G*6 = *N** (6:@) *Empty*

*G*4 = *N** (4:□, [*par*›7, *body*›6]) ([6›*arg*], 7) *G*6

*G*3 = *N** (3:@, [*fun*›4, *arg*›5]) (5) *G*4

*G*1 = *N** (1:□, [*par*›2, *body*›3]) ([6›*fun*], 2) *G*3

Now the meaning of the graph *G*1 is:

S[[*G*1]] = *S*'[[*the*(*root*(*G*1)), *G*1]] = *S*'[[1, *G*1]]

= □***d.****S*'[[3, *N* ([6›*fun*], 2:***d***) *G*3]]

= □***d.***(*S*'[[4, *N* ([6›*fun*], 2:***d***) *G*4]] (*S*'[[5, *N* (5) *G*4]]))

= □***d.***(□***d'.****S*'[[6, *N** ([6›*arg*], 7:***d'***) ([6›*fun*], 2:***d***) *G*6]]) □)

= □***d.***(□***d'.****S*'[[6, *N** (6:@, [*fun*›2, *arg*›7]) (2:***d***) (7:***d'***) *Empty*]]) □)

= □***d.***(□***d'.***(*S*'[[2, *N** (2:***d***) (7:***d'***) *Empty*]] (*S*'[[7, *N** (2:***d***) (7:***d'***) *Empty*]]))) □)

= □***d.***(□***d'.***(***d d'***) □)

= □***d.d*** □

Note that *S*'[[5, *N* (5) *G*4]] = □□because the semantics of free variables is not defined. Thus the meaning of the VEX picture is a function that applies its argument to the undefined value.

3.3 Show and Tell

In this section we consider abstract syntax and semantics of a more complex visual language: Show and Tell. The language is interesting for two reasons: first, it is a member of the rather large class of *data flow* languages and thus indicates how semantics could be defined for many other visual languages. Second, it demonstrates the effective use of nested syntax graphs which goes beyond grammatical descriptions of visual languages. Show and Tell (STL) according to [28], combines data flow with the concept of *completion*, which means to fill in empty boxes in a data flow graph by either computation or database search. Computations are represented by so-called *box-graphs*, which are acyclic directed multigraphs whose nodes are rectangles connected by arrows. A box is empty or it contains either simple data, such as numbers or functions, or another whole box-graph. In that case the box is called *complex* and can be either *closed* or *open*. Data can flow along the arrows from one box to another.

Whenever two boxes connected by an arrow contain different values, the box-graph is said to be *inconsistent*. An open box containing an inconsistent box-graph propagates this inconsistency, that is, the box-graph containing the inconsistent box also becomes inconsistent. In

contrast, when a closed box gets inconsistent, all that happens is that the box cannot receive or propagate any values, that is, an inconsistent closed box can be viewed as deleted. With the concept of inconsistency, conditionals can be expressed without having boolean values. The program contains two parameters (the two topmost empty boxes) and one result (the empty box on the left). If both arguments are "1", then the upper (closed) complex box remains consistent, and the "1" can flow directly into the result box. Moreover, the lower (closed) complex box gets inconsistent and cannot emit the "0". On the other hand, if one argument is "0", then the upper complex box gets inconsistent and cannot send data to the result box and to the lower box. Then, the "0" can flow from the lower box into the result box.

We choose an abstract syntax that mainly follows the concrete syntax. In particular:

(1) Nodes are labeled by constants (for example, integers), function symbols (such as +), (representing empty STL boxes), and complete graphs. Additionally, they carry an *open* or *closed*-tag. (In the following we will mention these tags only when needed.)

(2) Edges are labeled by pairs (i, j) where i means that the edge contributes to the ith parameter of the target node and j says that the jth component of the value at the edge's source node flows via this edge. If j=*, this means that the complete value flows via the edge.

(3) Each edge $e = (v, w):(i, j)$ (that is, from v to w with label (i, j)) that crosses a border of a complex box u is replaced by a new node x with label k (lying inside u) and two edges $e1$ and $e2$ as follows:

(i) If w is inside u, then $e1 = (v, u):(k, j)$ (ending at u) and $e2 = (x, w):(i, *)$ (connecting x to the target of e).

(ii) If v is inside u, then $e1 = (v, x):(1, j)$ and $e2 = (u, w):(i, k)$.

Here, k ranges from 1 to n (m) for all n incoming (m outgoing) edges and represents the argument position of the node.

(4) The (top-level) box-graph is extended according to rule (3) as if it were enclosed by a (closed) box having edges ending at the roots and leaving the sinks.

Nodes with constants as labels are surrounded by circles and can thus be distinguished from newly introduced nodes. Formally, we use integers as labels of newly introduced nodes and quoted integers as constant labels. This means, the label of node 4 is 2 whereas the label of node 8 is ´1.

If *OP* is the set of constants and operations used by STL programs, then STL abstract graphs without complex boxes have type □(□0, □) with (let ´IN= {´}□□IN):

□0 = (*OP* □□{ } □□IN □□´IN) □□{*open*, *closed*}

□□= IN □□(IN □□{*})

Since complex boxes are represented by nodes labeled with abstract STL graphs, the node type can be inductively defined to include graphs of increasing nesting:

□i+1 = □i □□□(□i, □)

Hence, the type of arbitrary STL abstract syntax graphs is given by □□= □i □□0 □(□i, □).

We can now define the semantics of each STL DAG as a function ***D****n* □□***D****m* when we take a domain of semantic values ***D*** (for example, for integers) and add to it a special value □□for dealing with inconsistency (see below). The first equation selects all roots of the graph, assigns ***D*** variables as new labels, and yields a function over these variables: *S*'[[*N** ([], *v*1:1, *s*1) … ([], *vn*:*n*, *sn*) *g*]] = □(***d***1, …, ***d****n*).*S*'[[*N** ([], *v*1:***d***1, *s*1) … ([], *vn*:***d****n*, *sn*) *g*]]

The used cascade pattern with the ellipsis extends as far as possible, that is, it selects all nodes labeled

by integers and having no predecessors. The recursive application of *S*' denotes the result tuple (by applying another semantic function *S*'' to all sinks of the graph) together with the consistency status of the whole graph given by *C*.

S'[[*N** ([*p*1], *v*1:1, []) … ([*pm*], *vm*:*m*, []) *g*]] = ((*S*''[[*p*1, *g*]], …, *S*''[[*pm*, *g*]]), *C*[[*g*]])

(Note that by definition of abstract syntax each sink has exactly one predecessor.) *S*'' moves in reverse direction through the abstract graph: it recursively determines the tuple of values for all predecessors and applies the function denoted by the current node to it. This function is denoted by the semantic function *F* defined below. In the pattern we assume that the predecessors (*pi*) are ordered with respect to the first label component (*i*) of the connecting edges. This ensures that the parameters appear in the correct order. Note that the values of the predecessors are not taken as a whole, but only the specific components as specified by the second label part (*si*) of the connecting edges. This is achieved by the application of projecting functions □*si* (where □*(*x*) = *x*).

S''[[*v*, *N* ([*p*1›(1, *s*1), …, *pk*›(*k*, *sk*)], *v*:*f*) *g*]] = *F*[[*f*]] (□*s*1(*S*''[[*p*1, *g*]]), …, □*sk*(*S*''[[*pk*, *g*]]))

The semantic functions *S*' and *S*'' only define the meaning of consistent STL-graphs. An inconsistent node or graph is defined to return the value □□which is defined to be equal to all other values of ***D***. In this way, an inconsistent (closed) node that is connected by an edge to a node *v* that is labeled by a constant or not labeled at all does not affect the result of *v*. A graph is inconsistent if any of its open nodes is inconsistent. Let *open* be a predicate that is true only for open nodes. The consistency of nodes/graphs is denoted by *C*'/*C*: *C*'[[*v*, *G*]] = (*open*(*v*) □□*S*''[[*v*, *G*]] □□□) *C*[[*G*]] = □*v* □□*VG*: *C*'[[*v*, *G*]]

Now the semantics of an STL graph is finally given by:

{

□ □□(*S*'[[*G*]]) if □□(*S*'[[*G*]]) *S*[[*G*]] = □

□□□ otherwise

If *G* contains no open boxes, the propagation of inconsistency need not be taken into account because in that case *C*' and *C* always yield *true*. Thus the semantics for graphs without open boxes simplifies to:

S[[*G*]] = *S*'[[*G*]]

S'[[*N** ([*p*1], *v*1:1, []) … ([*pm*], *vm*:*m*, []) *g*]] = (*S*''[[*p*1, *g*]], …, *S*''[[*pm*, *g*]])

It remains to define the functions denoted by node labels. An operation on ***D*** (like +) denotes itself. A constant *c* is interpreted as a function that checks whether all incoming values are equal to *c*, and an unlabeled node checks all incoming values for equality. Finally, the semantics of a node labeled by a complete STL graph is given by *S*.

F[[*f* : ***D****n* □□***D****m*]] = *f*

F[[*c* : ***D***]] = □(***d***1, …, ***d****n*).*if* ***d***1=…=***d****n*=*c then c else* □

F[[ ]] = □(***d***1, …, ***d****n*).*if* ***d***1=…=***d****n then* ***d***1 *else* □

F[[*G* : □]] = *S*[[*G*]]

The first line includes the case for constant labels, that is, *n*=0. This means in particular, that the definition of *S*'' reduces in this special case to:

S''[[*v*, *N* ([*p*1›(1, *s*1), …, *pk*›(*k*, *sk*)], *v*:***d***) *g*]] = ***d***

4. Conclusions and Future Work

We have presented a general framework for teaching the specification of visual language semantics with a view to making distinction with other instructive counter example for visual languages like Visual Basic, Visual C#, Visual J#, etc which are under Microsoft Visual Studio and not visual languages. A rather unrestricted form of abstract visual syntax given by graphs is the backbone of the formalism. The approach applies to quite a wide range of visual languages, and we can

even employ different semantics formalism, such as denotational or logical semantics.

A drawback of the approach presented so far is that visual information is mapped completely to a textual description. We are currently extending the formalism by a heterogeneous, that is, semi-visual, notation so that certain relationships, such as adjacency or intersection, need not be encoded in graph edges, but can be kept in visual form [35]. This will make semantics definitions and other transformations much more readable.

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Figures

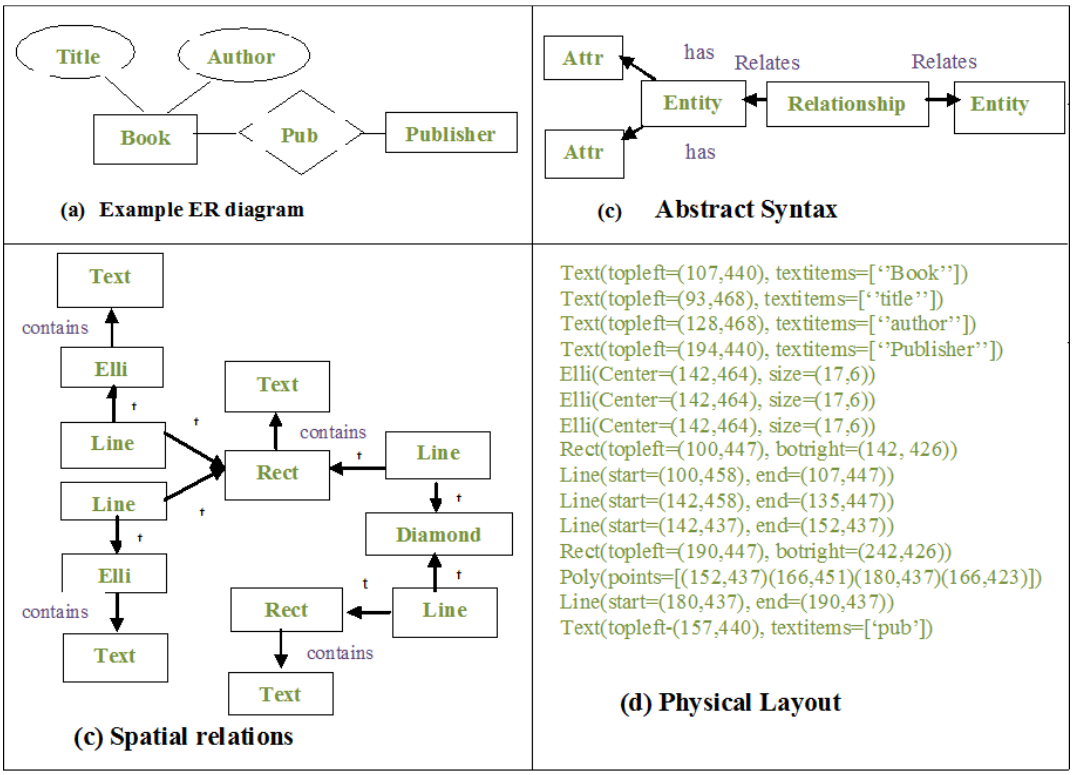


Figure 1. The Internal Representation of a Diagram

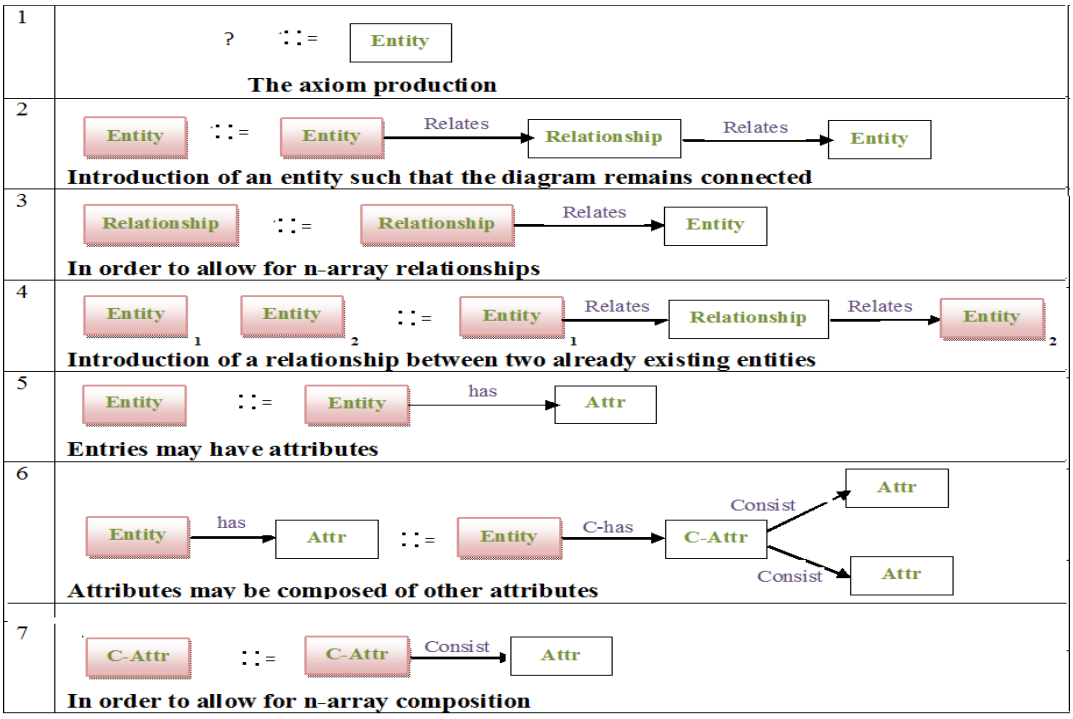


Figure 2. The Grammar for correct ER abstract syntax graphs

Figure 3. Euler Diagrams

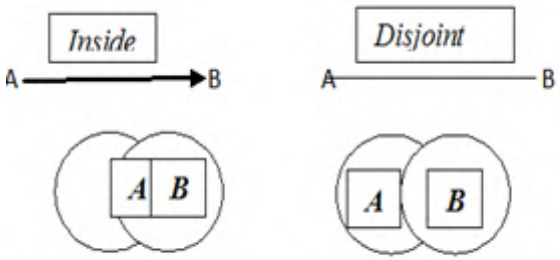


Figure 4. Abstract Syntax Graph for Euler Diagrams

Trends in annual maximum and minimum temperature data in New South Wales, Australia

Orpita Urmi Laz
School of Engineering
Western Sydney University
NSW, Australia
30054709@westernsydney.edu.au

Ataur Rahman
School of Engineering
Western Sydney University
NSW, Australia
A.Rahman@westernsydney.edu.au

***Abstract*—**This study examines trends in annual maximum temperature (AMaxT) and annual minimum temperature (AMinT) data at six stations in NSW. This adopts the Mann-Kendall trend test at 10%, 5% and 1% significance levels. The data period covers 51 years (1968 to 2018)**.** A positive (increasing) trend in AMaxT data is identified for all the six stations at 10% significance level. The trend is insignificant at 1% significance level. For 5% significance level, only two stations show significant trend. January is found to be the hottest month, followed by December and February. Some stations show the highest annual temperature in October (early summer). Further study aims at including a large number of stations to examine temporal and spatial changes in Australian temperature by developing temperature-duration-frequency curves.

Keywords—Annual Maximum Temperature, Annual Minimum Temperature, Mann Kendall Test, Normal Distribution, Trend Analysis.

I. INTRODUCTION

Globally, a rising of mean surface temperature has been visualised which varied between 0.1 to 0.2 ^{0}C per decade and the rate is greater compared to the pre-industrial times [1]. Changes in rainfall and sea level relate to the change in warming trends, appeared in decadal and century scale. Increase of the greenhouse gas concentration caused by the anthropogenic activities has detrimental impacts on the ecosystems. In the decade 2006 – 2015, the mean surface temperature was found to be 0.87 ^{0}C greater than that of in 1850 – 1900, as noted in the current report of the Intergovernmental Panel on Climate Change (IPCC) [1]. Numerous scientific studies have concluded that the night-time temperature has exceeded in greater number and intensity than the temperature at daytime in many parts of the world [2,3]. Particularly in northern half of Australia, the temperature varies 0.96 ^{0}C for maxima and 0.56 ^{0}C for minima per century [4]. Future prediction for the annual mean temperature points rising of 0.4-2.0^{0}C in 2030 (considered 1990 as a base period) while for the year 2070 it is 1.0 – 6.0 ^{0}C [5].

Since 1910, the mean temperature of Australia has experienced a positive increment and raised by about 0.8 ^{0}C [4]. Murphy and Timbal [6] demonstrated that most of the positive trends in maximum temperature occurred across South East Australia since 1950. The warmest year in Australia was 2013 on record, whereas 1990's and 1980's was recognized as the warmest and the second warmest decades [7, 8]. Most part of the country, notably Queensland and the southern half of Western Australia dealt with greatest warming since 1910. The rise of mean temperatures was greater than 0.1^{0}C per decade during this period [4].

High temperatures associated with dry weather have an adverse impact in agricultural environment as well as in economy. Due to the extensive drying of vegetation around the country, numerous catastrophic Bushfires happened in Victoria on February 2009, which was one of the worst Bushfire events in Australian history, designated as the "Black Friday". About more than 170 million people have been died and the financial loss was about A$1.02 billion as claimed by the insurance [9]. Record-breaking heat wave existed in Victoria with an approximate rise of 49 ^{0}C.

Detection and features of climate change are of great interest to the scientific community [10]. Climate extremes pose a threat to governments, industries and communities as well, which is increasing over the years and not well comprehended. Among various climate variables, temperature is one of the major ones to assess variations regionally and globally as it drives other factors such as rainfall. In the Fifth Assessment Report (AR5) of IPCC 2013 [11], it was stated that 'Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes'. Prolonged periods of intense temperature have significant detrimental impacts on human health, infrastructure, socio-economic aspects and natural biodiversity [12, 13]. Australia is the world's second driest inhabited continent on earth [14]. Average rainfall in 2018 was 412 mm, less than the 1961-1990 mean of 465 mm, represents the 39th driest year in record between 1900 to present [7]. Although the change in climate indices have been reported globally, its influence varies on regional level [15-17].

Since significant changes in Australian temperature is being observed as noted by many studies [18-20], it is important to examine the nature of this change in a greater depth over space and time. Intensity-frequency-duration (IFD) curves for design rainfall is widely used in practice. Likewise, the Temperature-Duration-Frequency (TDF) curves correlate the intensity of heat events of different durations to their return periods, can be an effective tool for extreme weather analysis (such as bushfires and floods) [12]. In this regard, this study examines changes in temperature data for a number of selected stations in New South Wales (NSW), Australia.

II. STUDY AREA AND DATA PREPARATION

For this study, temperature data from six NSW stations are analysed (Table I). The locations of these stations are shown in Figure 1. Two of these stations are from Newcastle, one from Parramatta, one from Sydney Airport and one from Canterbury-Bankstown and one from Black town area. The study period covers 1968-2018 for all the selected stations. Data were obtained from the Australian Bureau of Meteorology [7].

Annual maximum temperature (AMaxT) and annual minimum temperature (AMinT) series were constructed based on the daily maximum and minimum temperatures data at each of the selected stations.

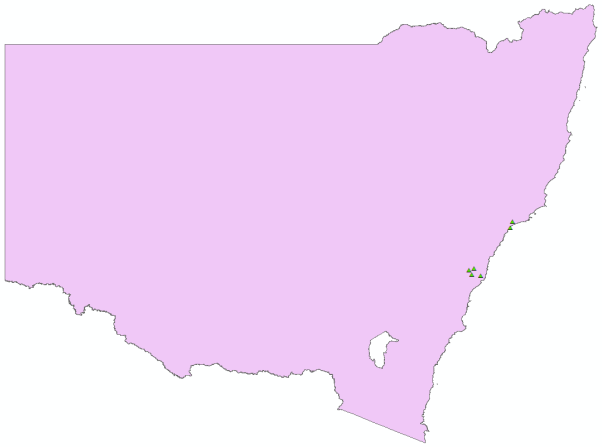


Fig 1. Locations of selected stations to examine trends in temperature

There were few gaps in some of the stations' temperature data. These gaps were infilled by the simple interpolation procedure based on serial correlation using the R software.

III. Methodology

Mann-Kendall (MK) test [21–24], a non-parametric method, is adopted for evaluating trends in temperature data. The reason for adopting this nonparametric method is that this test is not sensitive to outliers in the data series.

In this test, it is assumed that the temperature data ($X_1, X_2, \ldots, X_n$) are a sample of n independent and identically distributed random variables. The test statistic in the MK test can be written as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \sin(X_j - X_i) \tag{1}$$

where X is the time-series data to be tested, n is the data length, and sign can be obtained by:

$$\sin(X_j - X_i) = \begin{cases} +1 & (X_j - X_i) > 0 \\ 0 & \text{if } (X_j - X_i) = 0 \\ -1 & (X_j - X_i) < 0 \end{cases} \tag{2}$$

As suggested by Mann (1945) and Kendall (1975), the statistic S can be described by a normal distribution approximately when $n \geqslant 10$, having mean and variance as below:

$$E(S) = 0 \tag{3}$$

$$var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{q} t_i\,(t_i-1)(2t_i+5)}{18} = \sigma^2 \tag{4}$$

where t_i is ties of magnitude 1 to q, and q represents the number of groups forming ties. The standardized test statistic (Z) can be specified by:

$$Z = \begin{cases} \dfrac{S-1}{\sigma} & \text{for } S > 0 \\ \dfrac{S+1}{\sigma} & \text{for } S < 0 \\ 0 & \text{for } S = 0 \end{cases} \tag{5}$$

The null hypothesis of no trend can be rejected at a significance level if $|Z| > Z\alpha_{/2}$, where $Z\alpha_{/2}$ is the standard normal variate having exceedance probability equal to α/2.

IV. Results and Discussions

Table I presents summary of results by the MK test for the AmaxT data series. At 10% significance level, all the six stations show significant positive trends (with the p-values less than 1 and the z values being positive) for the AmaxT data. The trends are significant at 5% significance level for two of the six stations, Parramatta North (066124) and Prospect Reservoir (067019). At 1% significance level, none of the six stations exhibits trends in the AmaxT data. The AMaxT series for the six stations show a rate of rise between 0.03 ^{0}C to 0.08 ^{0}C per year (as can be seen from Figure 2). This is equivalent to 0.3 to 0.8 ^{0}C increasing rate per decade.

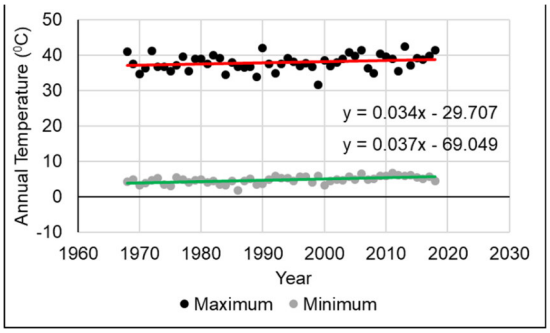
TABLE I. Selected stations and estimated Mann Kendall test STATISTICS for Annual Maximum Temperature data

Station Name	Station ID	Z	p	S	Var S (×10^4)	τ
Newcastle Nobbys Signal Station AWS	061055	1.8367	0.0663	227	1.5141	0.179
Williamtown RAAF	061078	1.9099	0.0562	236	1.5140	0.186
Sydney Airport AMO	066037	1.6661	0.0957	206	1.5139	0.163
Parramatta North (Masons Drive)	066124	2.3491	0.0188	290	1.5136	0.229
Bankstown Airport AWS	066137	1.9097	0.0562	236	1.5142	0.186
Prospect Reservoir	067019	3.3722	0.0007	416	1.5144	0.328

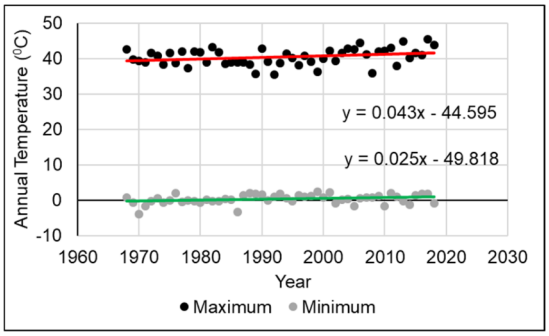
TABLE II. Selected stations and estimated Mann Kendall test STATISTICS for Annual Minimum Temperature data

Station Name	Station ID	Z	p	S	Var S (×10^4)	τ
Newcastle Nobbys Signal Station AWS	061055	3.485	0.0005	442	1.6010	0.338
Williamtown RAAF	061078	1.808	0.0705	230	1.6032	0.175
Sydney Airport AMO	066037	5.300	0.0	672	1.6029	0.512
Parramatta North (Masons Drive)	066124	0.669	0.0188	-55	1.6000	-0.042
Bankstown Airport AWS	066137	0.726	0.4674	93	1.6027	0.709
Prospect Reservoir	067019	-1.392	0.1639	-177	1.5981	-0.136

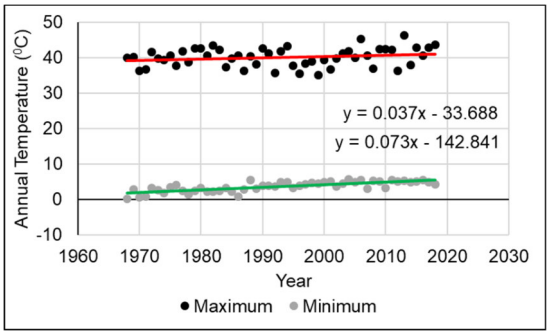
In order to determine the degree of linear correlation of variables in regression analysis, the coefficient of determination is an essential tool. The coefficient of determination R^2 is an ordinary reported statistic, because it represents the proportion of variance explained by a linear model. R^2 can vary from 0 to 1. Fig 1 shows the value of coefficient of determination, between the year and the annual maximum temperature ranges between 0.04 and 0.23 indicating a weak correlation.



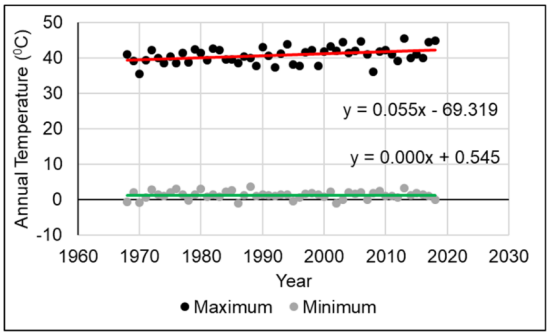
(a)



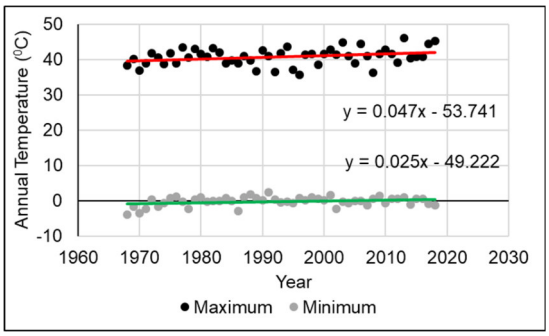
(b)



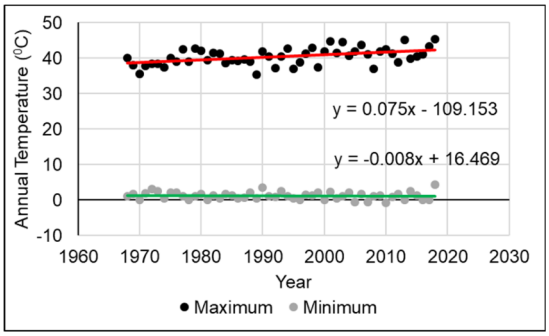
(c)



(d)



(e)



(f)

Fig. 2. Trend in Annual Maximum Temperature data at Newcastle station (a, b), Sydney Airport station (c), Parramatta station (d), Bankstown Airport Aws (e), Prospect Reservoir (f)

For the AMinT series, a significant positive trend is found for five out of the six stations at 10% significance level. The rate of rise here is 0.04 ^{0}C to 0.07 ^{0}C per year for the five stations (shown in Fig 2). The increase and decrease rates in the AMaxT and AMinT data series are summarised in Table III for all the selected stations. In case of Newcastle Nobbys Signal Station AWS and Sydney Airport AMO, AMinT has a higher rate of increase than the AMaxT, which agrees with the findings of previous studies [25-28].

TABLE III Rate of change in annual maximum temperature (AMaxT) and annual minimum temperature (AMinT) data from 1968 through 2018 for the selected stations in NSW

Rate of Change in AMaxT and AMinT (°C/year)						
Station Name	***Newcastle Nobbys Signal Station AWS***	***Williamtown RAAF***	***Sydney Airport AMO***	***Parramatta North (Masons***	***Bankstown Airport Aws***	***Prospect Reservoir***
AMaxT	0.034	0.043	0.037	0.055	0.047	0.075
AMinT	0.037	0.025	0.073	0.00	0.025	- 0.008

Fig 3 shows Australia has warmed by just over 1 ^{0}C since 1910, and most of the warmings have occurred since 1950 [7]. Fig 4 shows the anomalies (deviations from the average) of the AMaxT series for the six stations and it is seen that for most of the stations, there are many positive values after around 1989 as compared with those before 1989. This indicates a warmer phase after 1989 for these stations. The anomaly for the AMaxT is the greatest for Prospect Reservoir station (Fig 4).

Fig 4 also shows the anomaly in AMinT data for the six stations. It can be seen that AMinT is increasing since around 1992 and the greatest increment takes place for Sydney Airport AMO station where all the years after 1996 have AMinT values higher than the long-term average (considering 1968-2018).

For both the AMaxT and AMinT series, the last 5 years (2014-2018) have higher than the average values for all the six stations indicating that the temperature rise is highly evident in recent years.

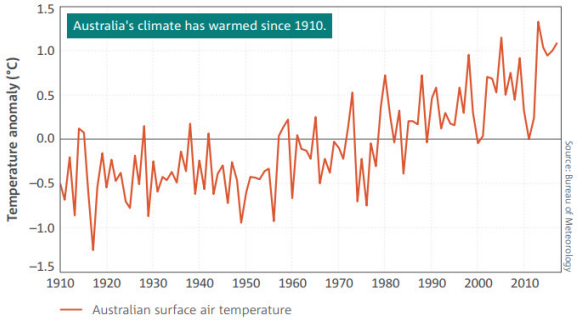
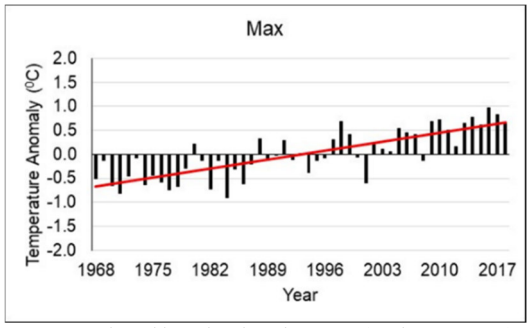
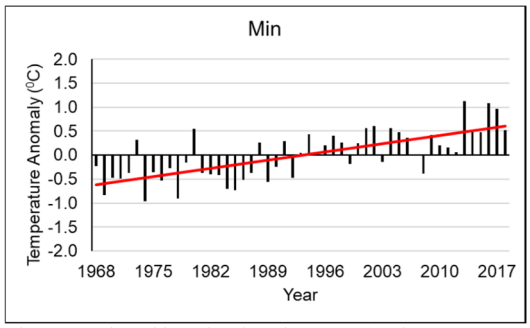


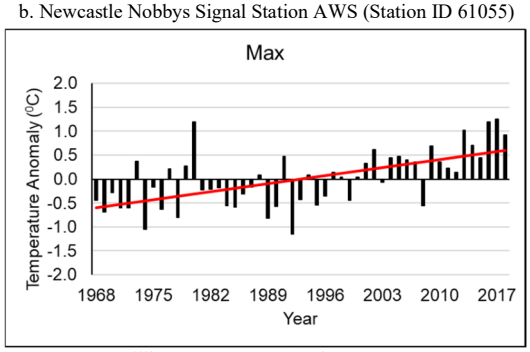
Fig 3. Anomalies in annual temperature over land in Australia (source: BOM website).



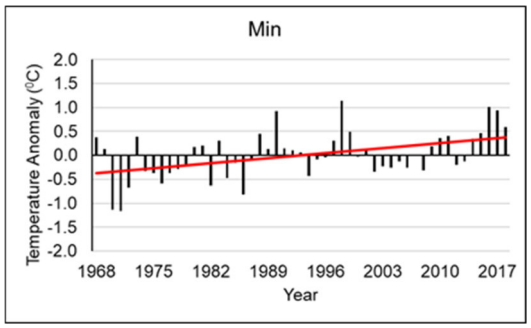
a. Newcastle Nobbys Signal Station AWS (Station ID 61055)



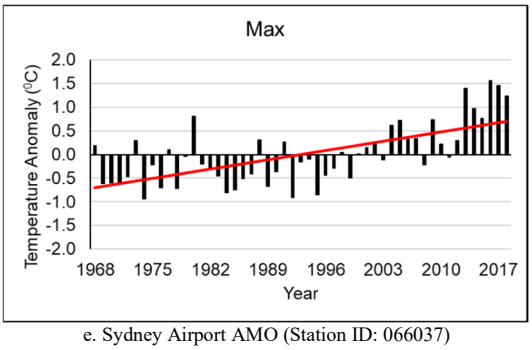
b. Newcastle Nobbys Signal Station AWS (Station ID 61055)



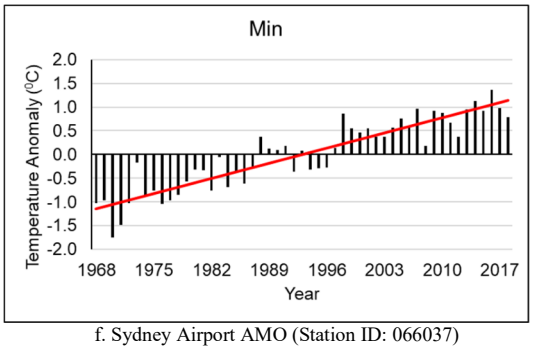
c. Williamtown RAAF (Station ID: 61078)



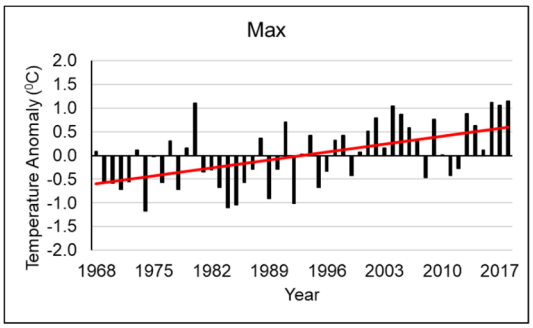
d. Williamtown RAAF (Station ID: 61078)



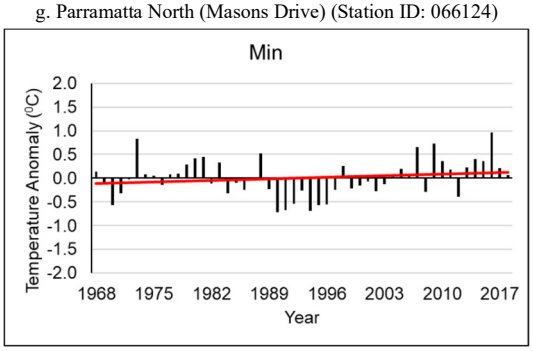
e. Sydney Airport AMO (Station ID: 066037)



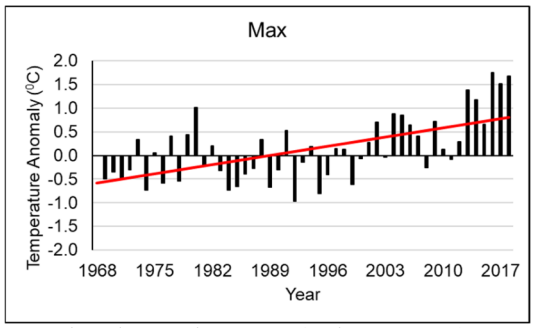
f. Sydney Airport AMO (Station ID: 066037)



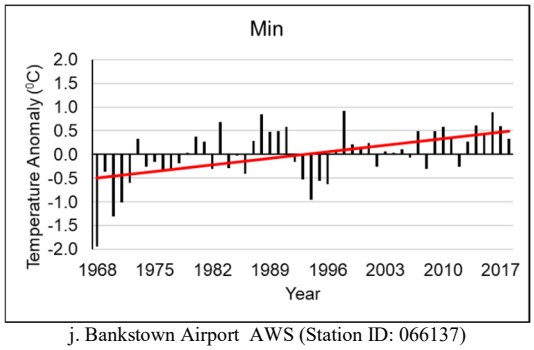
g. Parramatta North (Masons Drive) (Station ID: 066124)



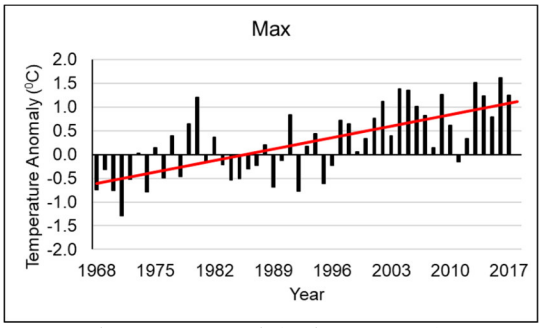
h. Parramatta North (Masons Drive) (Station ID: 066124)



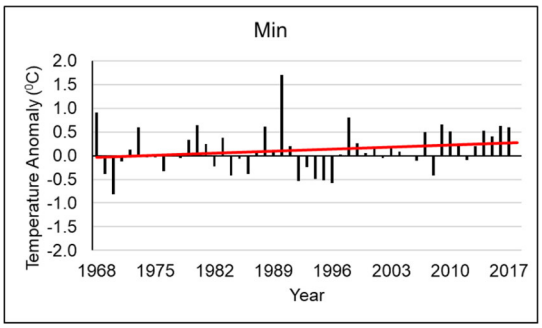
i. Bankstown Airport AWS (Station ID: 066137)



j. Bankstown Airport AWS (Station ID: 066137)



k. Prospect Reservoir (Station ID: 067019)



l. Prospect Reservoir (Station ID: 067019)

Fig 4. Anomalies analyzed in annual temperature for the six stations (1968-2017)

The hottest months in records from the data (1968-2018) are also examined for all the six stations. The results are summarized in Table IV. The frequencies of the highest annual temperature values are found to be falling in January (e.g. 10 times for Station 61055, 16 times for Station 61078, 14 times for Station 66037, 23 times for Station 66124, 7 times for Station 66137, 24 times for Station 67019). It is interesting to see that the highest temperature values have occurred in October in few cases (i.e. for Station 61055 - 2 times, 61078 - 3 times, 66037 – 1 time, 66124 – 1 time and in 67019 – 1 time), which is very early of summer season. Among the six stations, the highest temperature value is found to be 46.4 ^{0}C at Station 66037. It should be noted that the highest maximum temperature in Australia was recorded as 50.7 ^{0}C at Oodnadatta (South Australia) on 2 January 1960 [29]. Overall, December, January and February are found to be the hottest months for the six stations.

In Station 61078 (Williamtown RAAF), the temperature exceeded 45 ^{0}C, in station 066037 (Sydney Airport AMO) the temperature exceeded 46.4 ^{0}C, in station 066124 (Parramatta North (Masons Drive) temperature exceeded 45.5 ^{0}C, in station 066137 (Bankstown Airport AWS) exceeded 46.1 ^{0}C and in station 067019 Prospect Reservoir the temperature exceeded 45.3 ^{0}C as summarized in Table IV.

AMinT values have increased (Figure 4) over most of the stations over the years. Maximum AMinT temperature has found to be 6.8 ^{0}C in station 61055 in June.

TABLE IV: Monthly frequencies of AMaxT/ AMinT during 1968 – 2018.

Station	Month	Frequency		Range	
		AMaxT	AMinT	AMaxT (^{0}C)	AMinT (^{0}C)
61055	Jan	10	0	36.3 - 42.5	Nil
	Feb	12	0	39.1 - 40.9	Nil
	Mar	3	0	31.7 - 38	Nil
	Apr	0	0	Nil	Nil
	May	0	0	Nil	Nil
	Jun	0	14	Nil	3.0 - 6.8
	Jul	0	25	Nil	1.8 - 6.2
	Aug	0	12	Nil	3.5 – 6.0
	Sep	0	0	Nil	Nil
	Oct	2	0	34.9 - 35.5	Nil
	Nov	10	0	34.6- 41	Nil
	Dec	14	0	34.7 - 42	Nil
61078	Jan	16	0	35.4 - 44.8	Nil
	Feb	11	0	35.6 - 45.5	Nil
	Mar	2	0	39 - 39.4	Nil
	Apr	0	0	Nil	Nil
	May	0	0	Nil	Nil
	Jun	0	4	Nil	-1.8 - 1.7
	Jul	0	29	Nil	-3.9 – 2.0
	Aug	0	17	Nil	-1.7 – 2.3
	Sep	0	1	Nil	0.4
	Oct	3	0	35.9 - 38.3	0
	Nov	9	0	38.1 - 43.2	0
	Dec	10	0	38.5 - 42.8	0
66037	Jan	14	0	35.1 - 46.4	Nil
	Feb	12	0	36.2 - 42.9	Nil
	Mar	0	0	Nil	Nil
	Apr	0	0	Nil	Nil
	May	0	0	Nil	Nil
	Jun	0	11	Nil	2.2 - 5.4
	Jul	0	31	Nil	0.1 - 5.6
	Aug	0	8	Nil	1.8 - 5.4
	Sep	0	1	Nil	5.1
	Oct	1	0	37	Nil
	Nov	8	0	35.4 - 43.4	Nil
	Dec	16	0	36.2 - 43.2	Nil
66124	Jan	23	0	36.1 - 45.5	Nil
	Feb	10	0	38.5 - 44.5	Nil
	Mar	0	0	Nil	Nil
	Apr	0	0	Nil	Nil
	May	0	1	Nil	1.4
	Jun	0	13	Nil	0.8 - 2.7
	Jul	0	29	Nil	-1 - 3.7
	Aug	0	7	Nil	0.7 - 3.2
	Sep	0	1	Nil	0.7
	Oct	1	0	40.1	Nil
	Nov	9	0	38.2 - 42.7	Nil

Station	Month	Frequency		Range	
		AMaxT	AMinT	AMaxT (^{0}C)	AMinT (^{0}C)
	Dec	8	0	35.6 - 43.9	Nil
66137	Jan	20	0	35.6 – 46.1	Nil
	Feb	10	0	38.9 – 44.5	Nil
	Mar	0	0	Nil	Nil
	Apr	0	0	Nil	Nil
	May	0	0	Nil	Nil
	Jun	0	13	Nil	-1.8 – 0.6
	Jul	0	28	Nil	.4.0 – 2.3
	Aug	0	10	Nil	-0.7 – 1.3
	Sep	0	0	Nil	Nil
	Oct	1	0	39.7	Nil
	Nov	9	0	37.0 – 43.1	Nil
	Dec	11	0	36.3 – 43.6	Nil
67019	Jan	24	1	37.1 - 45.3	0
	Feb	11	0	35.6 - 42.5	Nil
	Mar	0	0	Nil	Nil
	Apr	0	0	Nil	Nil
	May	0	2	Nil	1.3 - 4.4
	Jun	0	16	Nil	-0.8 - 3.6
	Jul	0	22	Nil	-0.6 - 3.2
	Aug	0	8	Nil	-0.5 - 2.5
	Sep	0	0	Nil	Nil
	Oct	1	1	39.0	0
	Nov	7	0	37.0 - 42.0	Nil
	Dec	8	1	35.4 - 42.7	0

V. CONCLUSIONS

Results of trend analysis show a general temperature increase for the annual maximum and annual minimum temperature data for the six selected stations in NSW. The overall trends in our temperature data agree well with the results of previous studies [30, 31]. The hottest month is found to be January, followed by December and February, whereas the coolest month is July. The maximum temperature is found to be 46.4 ^{0}C at Station 66037 (the recorded highest maximum temperature in Australia is 50.7 ^{0}C). Further study will include a large number of stations to examine temporal and spatial changes in Australian temperature data by developing temperature-duration-frequency curves.

ACKNOWLEDGMENT

Authors would like to acknowledge the Australian Bureau of Meteorology for providing temperature data for this study.

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Plenary Speech

Advanced Technologies to Engineer a Better Sustainable World

Marlene Kanga

President, World Federation of Engineering Organisations, UK

Abstract

The UN Sustainable Development Goals were approved by member nations in September 2015 and provide an integrated approach to development which brings together objectives for people, prosperity and concerns for the planet. The world has 11 years to implement the 17 Goals and 169 targets of this ambitious agenda. There is no time to lose, especially for engineers as every one of the 17 Goals involves engineering. Dr Kanga has led the World Federation of Engineering Organisations with a commitment by its members from 100 nations, and its partners, to develop and implement solutions that advance the achievement of the Goals. Her presentation will cover the opportunities for advanced technologies to advance the UN Sustainable Goals and the strategies being used by the Federation to engage with the United Nations and its various agencies such as the UN Framework Convention for Climate Change (UNFCCC) and UNESCO. She will showcase the UNESCO Engineering Report which will be released in November 2019 and which will also have the strong message of the role of engineering in sustainable development. She will also describe the work being undertaken by various committee of the Federation, especially in the area of advanced technologies and the work of the member and associates of the Federation and projects being undertaken through partnerships between international organisations in engineering, especially for the celebration of the first World Engineering Day for Sustainable Development on 4th March 2020.

Keynote Speech

Augmenting Laboratories: Improved Linking of Theory and Reality

David Lowe

Deputy Dean, Faculty of Engineering, The University of Sydney, Australia

Abstract

Laboratory-based education can provide significant benefits in supporting student learning. However whilst other areas of education have benefited from technological innovation, the same is often much less true of laboratories. Augmented reality provides an opportunity to dramatically enhance the learning experience of students. Imagine a magnetics experiment where the view of the equipment is overlayed with a representation of the magnetic field, or a structures experiment where students can see the strain in the various structural members. In this talk the opportunities for reshaping laboratory experiences and enhancing student learning will be explored.

Keynote Speech

Engineering Education in Bangladesh at Postgraduate Level

Muhammed Alamgir

Member, University Grants Commission of Bangladesh, Bangladesh

Abstract

Laboratory-based Bangladesh becomes an emerging country of economic progress having continuous growth of GDP for more than a decade. The country has the commitment to achieve SDGs by 2030 and to become a developed country by 2041. In the meantime, the world has entered into the Fourth Industrial Revolution (4IR). The uncertainty of 4IR is that one cannot even imagine in what scale the society and the planet will be changed. So Bangladesh has been preparing her giving special emphasis to higher education, specially engineering education at postgraduate level to face the challenges. Presently, in Bangladesh, the number of students accumulated in all levels reach to about 40 millions, in which the students at the tertiary level rise as much as more than 4miliions. The number student at the postgraduate level is nearly 0.30million studied in 40 public universities including colleges and 87 private universities. However, due to inherent constraints of having international standard laboratories, resource persons, relevant facilities and funding, and also to have the opportunities of getting job after bachelor degree in engineering education, the number of student at postgraduate level is not encouraging. However, the government has taken several initiatives through University Grants Commission of Bangladesh to improve research facilities and scholarship in the universities to enhance engineering education at postgraduate level.

Keynote Speech

Engineering Education in Australia: Current Trends

Roger Hadgraft

Director, Educational Innovation, Faculty of Engineering and Information Technology,
University of Technology Sydney, Australia

Abstract

We live in exciting, if troubling times. Technologies are accelerating, providing undreamed of convenience, the most obvious ones being the mobile phone in your pocket or the smartwatch on your wrist. At the same time, wealth is increasingly concentrated in the hands of the few and climate catastrophe is looming due to global heating. We need to be preparing graduates for this exciting but uncertain world. Students must learn to unpack complex situations, ask deep questions, and synthesise new solutions to satisfy the social context. Technology, by itself, is not the answer; students must learn to engage with clients and stakeholders. Innovation and entrepreneurship are key skills, not just in commerce but in leading social change. In Australia, the engineering education landscape is continually growing, with increasing student numbers, both domestic and international, but with fewer resources due to capped funding. Research output has never been more important. There is also pressure for programs to be more multidisciplinary, emphasising social aspects of engineering solutions. Employers want more broadly-capable graduates. Change is inevitable but difficult! This presentation will review some of the new programs and practices emerging in Australian universities and their fit for this changing world.

End Of Proceedings