Full Paper

Introduction

There is increasing need for graduates to understand and develop solutions for a myriad of sustainability problems. With increasing pressures from climate change, energy security together with the need for reducing material/resource efficiency right through to sustainability assessment and triple bottom line reporting, engineering graduate students will increasingly be required to demonstrate a skill set that meets the challenges of a changing world (Hasna, 2010).

Most Australian Universities are struggling with how they can ensure that their graduates have the required set of skills and knowledge in meeting these challenges (Rosano and Biswas, 2015). International universities are also seeking new teaching methods and pedagogy in sustainable engineering education (Filion, 2010). The Australian Sustainable Engineering Education Network Forum held in Sydney in June 2013 provided convincing evidence that industry is also facing major sustainability design and application challenges and needs more graduates to be suitably equipped for this work when they leave university.

The development of the SEC will provide an opportunity for students to engage hands-on in a sustainability problem solving activity as an individual or in group work. It is being developed as an activity to be utilised within the Final Year project domain or as a capstone unit which could assist in developing sustainable engineering and leadership skills in final year engineering students. This is similar to the method which has been applied in the UK where a similar competition is used within the Final Year project domain or as a capstone unit which assists in developing sustainable engineering and leadership skills in final year engineering students (Joyce et al, 2013).

The need for multidisciplinary teams working to respond to the challenges involved in complex problems in sustainability management have been acknowledged by previous research (Rhee et al, 2014; Tomkinson et al, 2008). In this regard, the SEC will be open to all engineering disciplines.

One or more supervisors at each university would be responsible for supervising and advising their project teams. The project would encompass networking opportunities for students with other university students involved in the Challenge and a number of formal lectures and presentations to guide and motivate the projects developed.

This paper will set out the conceptual design parameters for the Challenge and we seek a small group of implementers to help organise the Challenge for trial in 2017 and a broader national roll out in 2018.

It is also envisaged that sponsorship/financial support opportunities will provide prizes for this national Challenge which will be judged by leading Australian Energy Leaders and Innovators.

Recent history of sustainable engineering education discussion in Australia

Australian academics are just starting to collaborate in and around sustainable engineering education, with some shared learning resources recently published. Feedback from university academics and lecturers from workshops held at the Australasian Association for Engineering Education (A2E2) conferences in December 2011 (Perth) and December 2012 (Melbourne) indicated a need to review sustainable engineering content and pedagogy in Australia. The 2012 workshop suggested the development of a Sustainable Engineering Education Network (SEEN) to support the shift towards a more complex systems based approach to engineering education. SEEN was established as a result of this workshop.

In June 2013, a symposium was held at the University of Technology Sydney (UTS) to address the challenge of increasing the focus on sustainable engineering education at Australian universities, as well as the establishment of a formal network to help promote it. It was hoped that SEEN would act as a potential unifying structure and a necessary vehicle to achieve the education outcomes sought, including resource and information dissemination, capacity building and professional development in sustainable engineering education.

Funding was received from the Federal Government Department of Resources, Energy and Tourism (RET) to hold the event so that interested academics could attend free of charge apart from individual travels costs to Sydney. RET sponsored the event in order to assist with the development of a proposed roadmap and the building of a community of practice around sustainability and energy efficiency education in Australia. More than 40 academics from across Australia attended the symposium.

Potential solutions that were discussed across the two days in workshop format included the further development of a community of practice in sustainable engineering education, working with Engineers Australia to develop a new 'practice note' on sustainable engineering, the re-establishment of the Engineers Australia Education Committee, a program to work more closely with the Australian Council of Engineering Deans and the promotion of the sustainable engineering education 'cause'.

Follow up events organised by the Sustainable Engineering Education Network (SEEN) in Australia at the Australasian Association for Engineering Education (A2E2) conferences in 2013 and 2014, confirmed the need for engineering undergraduate degrees in Australia to include more sustainability focused learning activities and the need for more academic and industry based leadership contributing to and influencing the sustainable engineering education and the public sustainability agenda. These symposia have confirmed the need for more multidisciplinary based engineering education and that significant gaps exist in sustainable engineering education content, pedagogy and teaching and learning frameworks to assist teaching development in this arena.

The ability to include more core sustainable engineering competencies, skills and sustainability related knowledge in already busy engineering degrees has been a major challenge in itself for many academics wanting to increase the sustainable engineering content and skills taught currently in Australian undergraduate engineering degrees (Rosano and Biswas 2015).

There is an increasing need for graduates to engage in solving 'wicked' sustainability problems. With increasing pressures of climate change, environmental impact measurement, resource efficiency, material intensity, risk management and triple bottom line reporting, young engineering graduate students are increasingly being challenged to provide a skill set that meets the challenges of a changing world.

Faced with this dilemma, the organising committee of the SEEN network have for the past two years been working on a number of ideas on how to ensure that young graduates have the required set of sustainable engineering skills, knowledge and values upon graduation. This is where the idea of the Sustainable Energy Challenge was developed, based on the successful program developed by Engineers Without Borders and other engineering related sustainability competitions across the world. These influences will now be discussed further.

Engineers Without Borders Challenge

The EWB Challenge has a focus on humanitarian engineering in a sustainability context. The Challenge is delivered by many universities including Curtin University, the University of Melbourne, the University of Adelaide, RMIT, ANU, the University of Sydney, and so on. Through this Challenge, students are able to develop specific sustainability design skills and apply them to humanitarian and community based problems. Previous EWB Challenges have been held across a variety of countries including rural Australia, India, Vietnam, Timor

Leste and Nepal. The EWB Challenge is designed to be conducted in early semester courses in engineering, architecture and science (Engineers Without Borders, 2015).

Some of the previous challenges completed in the field of engineering and sustainability include:

- *Habitat for Humanity, Vietnam*
  This EWB challenge aimed to provide novel solutions for the sustainable development improvement in the Anh Minh district within the Kien Giang province on the Mekong Delta. Winning entries included (1) a *Ventilation project* where students employed different techniques including chimneys, open roof ventilation and coconut leaf insulation on the walls and (2) *Community hand washing station* where students designed a simple but innovative bamboo structure.

- *Nepal Water for Health*
  In collaboration with Nepal Water for Health (NEWAH), the EWB challenge provided opportunities for students to contribute in community projects for housing, drinking water, energy, waste management, transport, ICT and climate change. Winning projects Included (1) New design for cooking stoves and (2) *The TOM Box Education Facilitation Scheme* where students investigated the feasible options to facilitate education uptake.

- *Plan - Timor Leste*
  In collaboration with Plan TL, students participated in projects concerning sustainable development in Codo in Timor Leste. Topics included transportation, waste management and water supply. Winning projects included (1) a *Mosquito Trap* where students designed a trap made of used plastic bottles and nets and (2) *Cost effective Water Filtration* where students used ceramic pots for the purpose of water filtration.

- *Pitchandikulum Forest, India*
  In collaboration with Pitchandikulam Forest the challenge aimed to provide sustainable solutions for different community problems in Devikulam in East India. Topics included energy, water, housing and transportation. Winning projects included (1) *Organic Waste Management: a Vermicomposting solution* where student designed a mesh brick wall as a compost unit for houses and (2) *Devikulam Water Purification Project* where students designed a cost effective filtration system using commonly available materials.

- *Kooma Traditional Owners Association, Australia*
  In collaboration with Kooma Traditional Owners Association, students were given the opportunity to develop design solutions for community problems in the Murra Murra and Bendee Downs area in south-west Queensland. Topics included building design, transportation, energy and eco-tourism. The winning projects included (1) *Bendee Downs Eco-Tourism Proposal* where students proposed strategies for improving tourism development in the area and (2) *Solar Ice at Bendee Downs* where students used solar power on a condenser in the daytime and then used its cooling capacity at night time.

- *Live & Learn Environmental Education, Cambodia*
  In collaboration with Live & Learn Environmental Education program in Cambodia, students had the opportunity to participate in projects concerning community activities around the Tonle Sap Lake River system. Winning projects have included (1) a *bio-digester for a floating community* where people were living on boats.

There are now more than 30 Australian universities and more than 25 universities from UK, Ireland, New Zealand and Malaysia participating in the EWB Challenge. In Australia, the program is sponsored by the BHP Billiton Sustainable Communities and Anglo American Group Foundation. It is also supported by Engineers Australia, the Australian Council of Engineering Deans, Engineering Professors' Council (UK) and the Engineering Council (UK). This program has been successfully carried out since 2007.

Sustainability competitions across the world

In recent years, the concept of sustainability has also attracted the attention of many international educational and industrial institutions. Sustainability focused competitions and challenges have been used to promote community and industry concerns about sustainability. While there are numerous Challenges/competitions in this field, five major international Challenges are reviewed below:

- *Sustainability Innovation Student Challenge Award (SISCA)*

  This challenge is conducted by The University of Queensland in collaboration with the Dow Chemical Company. A AUD$10,000 award for the first place and AUD$2500 for the second place are financial incentive for participants. The program covers topics of sustainability including sustainable chemistry, climate change, energy efficiency and conservation, product safety and leadership and local protection of human health & the environment (Sustainability Innovation Student Challenge Award, 2015).

- *Morgan Stanley Sustainable Investing Challenge*

  The program is led by the Kellogg School of Management at Northwestern University, INSEAD and Morgan Stanley Institute for Sustainable Investing. A USD$10,000 first place and a USD$5000 second place award are the prizes for this challenge. Winners also receive a chance for internships and graduate programs. The program is seeking innovative potential investment proposals to meet changing global conditions (Morgan Stanley Sustainable Investing Challenge, 2015).

- *P3: People, Prosperity and the Planet Student Design Competition for Sustainability*

  This competition is conducted by the U.S. EPA and the Office of Research and Development in Washington with overall prize pool of USD$75,000. The competition is comprised of two stages where students of various disciplines in science and technology work as a team. The selected programs in Phase I receive grants to improve the project for Phase II (P3, 2015).

- *Sustainable Design Competition*

  The competition is conducted by NEWH Inc. where a total of USD$10,000 is distributed between two selected projects. The topics encompass water efficiency, energy conservation, materials and indoor environmental quality (Sustainable Design Competition, 2015).

- *SENG National Student Award*

  The competition is run by the Australian Sustainable Engineering Society (SES). This program aims to encourage participants to apply a sustainable engineering concept to a real application problem (Sustainable Engineering Society, 2015).

The authors of the winning project receive an Award certificate in recognition of their achievement. The winning project is invited to the SES biennial conference to present the project and their airfare and accommodation is paid by the SES.

Structure of the Sustainable Energy Challenge

The SEC will focus on sustainability as a key ingredient in the practice of engineering, with a particular focus on energy in its inaugural year: reducing energy use, energy efficiency, renewable energy and energy innovation. While students will be able to enter the competition as individual entrants, it is expected that most entries will be as groups. Rosano and Schianetz (2014) highlight the importance of co-operation and a participatory approach involving collective learning and social learning in solving complex sustainability problems. The group format will also be encouraged by the organising committee as an additional learning envi-

ronment for students in developing additional skills in group focused complex problem solving.

Engineers Australia Stage 1 competencies

The Challenge will align with the EA Stage 1 Competencies, specifically elements 1.5a, 1.6c, 1.6d, 2.1g, 2.3b, 2.4e, 2.4f and 3.1c (below).

1.5 *Knowledge of contextual factors impacting the engineering discipline*

a) Identifies and understands the interactions between engineering systems and people in the social, cultural, environmental, commercial, legal and political contexts in which they operate, including both the positive role of engineering in sustainable development and the potentially adverse impacts of engineering activity in the engineering discipline.

1.6 *Understanding of the scope, principles, norms, accountabilities and bounds of contemporary engineering practice in the engineering discipline*

c) Appreciates the principles of safety engineering, risk management and the health and safety responsibilities of the professional engineer, including legislative requirements applicable to the engineering discipline.
d) Appreciates the social, environmental and economic principles of sustainable engineering practice.

2.1 *Application of established engineering methods to complex engineering problem solving*

g) Identifies, quantifies, mitigates and manages technical, health, environmental, safety and other contextual risks associated with engineering application in the designated engineering discipline.

2.3 *Application of systematic engineering synthesis and design processes*

b) Addresses broad contextual constraints such as social, cultural, environmental, commercial, legal political and human factors, as well as health, safety and sustainability imperatives as an integral part of the design process.

2.4 *Application of systematic approaches to the conduct and management of engineering projects*

e) Is aware of the need to plan and quantify performance over the full lifecycle of a project, managing engineering performance within the overall implementation context.
f) Demonstrates commitment to sustainable engineering practices and the achievement of sustainable outcomes in all facets of engineering project work

3.1 *Ethical conduct and professional accountability*

c) Understands the accountabilities of the professional engineer and the broader engineering team for the safety of other people and for protection of the environment.

The Challenge will also provide scope for deepening capability in other Stage 1 outcomes, such as:

1.3. an in-depth understanding of specialist bodies of knowledge within the engineering discipline.
1.4. a discernment of knowledge development and research directions within the engineering discipline.
2.2. Fluent application of engineering techniques, tools and resources.
3.2. Effective oral and written communication in professional and lay domains.
3.3. Creative, innovative and pro-active demeanour.
3.4. Professional use and management of information.
3.5. Orderly management of self, and professional conduct.

3.6. Effective team membership and team leadership.

Challenge research groupings

The research groupings for the Challenge and potential project ideas include:

Sustainability improvements in energy production (oil, coal, LNG, propane)

- Reducing the carbon footprint of current fossil fuel production processes (more sustainable fossil fuel production processes)
- Reducing energy consumption in primary conversion of fossil fuels (improving energy management).
- Separation, sequestration and utilisation of carbon dioxide in fossil fuel production and or fossil fuel use (CO2 mitigation).

Sustainability improvements in fossil fuel use and storage (power production, energy storage and distribution)

- Improving fossil fuel based power generation technologies (ie Clean Coal technology-zero emissions)
- Reducing carbon footprint in fossil fuel based power generation process
- Recovery of waste heat for applications including co-generation (industrial symbiosis)
- Development of fuel cell systems (more effective or more cost efficient fuel cell systems)
- Sustainability improvements in the storage and distribution of energy

Renewable energy (biomass, solar, wind, wave, geothermal, cogeneration)

- Development of alternative feed stocks
- Increasing the efficiency of yield from the sun rays in solar energy production.
- Reducing costs of renewable energy production.
- Development of portable or small scale renewable energy systems.
- Improving solar design in building construction and materials.

Leadership in Energy and Environmental Design (LEED)

- Using Eco-design to improve the energetic efficiency of the systems through their life cycle.
- Energy systems design with low carbon footprint
- Manufacturing systems that reduce energy usage and minimise GHG production.
- Zero carbon energy infrastructure planning

Innovation in energy systems and production

- Intelligent systems to reduce energy use with energy management and control systems
- Reducing/mitigating the environmental impact of building energy use.
- Waste heat recovery for energy production
- Process intensification that minimises energy/exergy losses
- Hydrogen power production.
- Tri-generation technologies for simultaneous (residential and industry-scale) production of power, heating and cooling.
- Development of small scale power generation technologies

Operating Framework for the challenge

The Challenge will be run within the operations of the current capstone research/Final year Project structure within most Australian Engineering Schools in the fourth year of the BEng (or the second year of the MEng). It is envisaged that each university participating in the Challenge will nominate a 'Challenge Supervisor' who will be responsible for liaising with the Challenge participants, keeping them informed of Challenge timeframes and requirements,

and assisting in supporting and mentoring the students during the Challenge. The SEEN Challenge organising committee will liaise directly with the Challenge Supervisors in the early development of the program and throughout the year.

It is planned to hold a number of online workshops for students to engage with industry leaders and other students during the Challenge to facilitate learning and knowledge development.

Guidelines will be provided to the Supervisors of the Capstone/FYP projects that will stipulate the:

- Timeframes for the project
- Guiding principles for supervision
- Potential project ideas
- Judging guidelines

Sponsorship

Potential sponsors of the Challenge will be sought to provide funding for the prizes to be awarded, to act as mentors for the project groups and to participate on the judging panel. Such sponsorship will also assist in the promotion of not just the Challenge itself, but also the importance of sustainable engineering education. Sponsorship could include in-kind contribution from consulting and other engineering companies by providing mentoring to individual teams.

Conclusion

While it is still early days in the development of the Sustainability Energy Challenge, a number of key benefits can be outlined in demonstrating the potential value of this new education program.

Firstly, in terms of the purpose and remit of modern engineering, engineers are stewards of the planet and are responsible for infrastructure and planning decisions involving energy and material efficiency, waste management, eco and sustainable design and more 'fit for purpose' focus in our current economic and production paradigms. Engineering decision making can greatly assist in building a stable, secure, well educated, healthy and just society. Engineering is central to many of the sustainability challenges the world will face in coming years with burgeoning population growth, climate change and rising standards of living in the fast growing BRIC economies.

Secondly, sustainable engineering decision making is simply good practice that respects the values of the society in which it is situated and which involves proactivity, collaboration, systems thinking, value creation and ethical responsibility in the development of engineering outcomes. Sustainable engineering respects the importance of the 'triple bottom line' in guiding resource use, energy efficiency and eco-design within engineering decision making. Competencies supporting sustainable engineering are an integral part of a young engineers 'fit for purpose' engineering skill set. The Challenge will provide an opportunity to significantly supplement the sustainable engineering education that is provided at under-graduate level while also providing a sustainable engineering-practice-focused learning forum in the fourth and final year of their engineering degree.

Thirdly, while the Washington Accord provides very general guidelines on the content of modern engineering education, it is up to the accrediting body to determine the specific requirements. As has been highlighted in earlier discussion, Engineers Australia's requirements are quite broad and non-specific in their direction of sustainable engineering education pedagogy, content and application. The Challenge will help provide many engineering degrees with the opportunity to engage their final year students in a significant, self-directed learning exercise that will apply the sustainable engineering education they have learned in their degree while affording them the opportunity to pick up new knowledge and skills in the

development of the Challenge project.

Sustainable engineering is recognised as not being well embedded in Australian undergraduate engineering programs, and is typically dependent on a few staff with an interest in sustainable engineering education, many of whom, however, have not worked in industry for many years. In addition, collective intelligence is an essential ingredient in solving many of the sustainability challenges ahead and the Challenge will provide the opportunity for students to collaboratively work together, building on the strengths and capabilities of their team while developing the skills necessary to apply their problem solving skills to engineering practice. The Challenge will also importantly assist many young graduates in making the transition from young student engineers to young professionals as they move into their first engineering job.

Increasing the sense of purpose of young engineers via a national engineering competition in sustainable engineering will also help to strengthen the understanding and value young engineers will have for their ethical and stewardship responsibilities and their need to corroborate community expectations in their professional decision making. Young engineers need a modern education that helps them move beyond the project management and consultancy roles that have tended to define the profession in recent times. It is hoped that the Sustainable Energy Challenge will strengthen the systems thinking context that is needed in modern sustainable engineering decision making and provide an opportunity to both promote and motivate young engineer towards more focus on these responsibilities as they enter the profession.

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