A Program Level Approach to Community-Centred Engineering Education

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Structured Abstract

BACKGROUND

A combination of drivers, including accreditation competencies, globalisation and student interest, has led to numerous humanitarian and community-centred engineering programs and initiatives being incorporated into engineering degrees. In most institutions these are isolated opportunities for students typically consisting of a single course or project often built around a service learning component. In the UK and USA there are a small number of dedicated programs with multiple courses in the form of named degrees or minors that are available to undergraduate students.

PURPOSE

Many of the existing humanitarian engineering education initiatives have a single focus such as international development or are only available at one year level. However, humanitarian or community-centred engineering takes a number of forms from working with local groups through to international development and emergency response. In order for students to gain a more complete understanding of humanitarian and community-centred engineering it was proposed that students should be provided with multiple related opportunities covering the many different aspects of this type of engineering, throughout their degree program.

DESIGN/METHOD

Informed by analysis and evaluation of literature and existing programs, a semi-structured pathway was created within the core courses of a four-year engineering degree program. This consisted of a number of opportunities that exposed students to different aspects of community-centred and humanitarian engineering. This allowed students with an interest in the field to be engaged in opportunities throughout their degree program.

RESULTS

Students are now able to select project topics and opportunities that have a focus on humanitarian or community-centred engineering throughout their degrees. These range from a general introduction to international development through to direct engagement with local community organisations, and from research-based projects to immersive and service learning experiences. Individual initiatives have received positive responses from students utilising those opportunities and initial feedback from local partners has also been positive. The development of this semi-structured pathway has also highlighted the need for strong ongoing links with external organisations engaged in humanitarian and community-centred work, a point which has also been emphasised in other research.

CONCLUSIONS

A series of linked student opportunities has been integrated into core compulsory courses of a four-year engineering degree program, which has allowed students to experience different aspects of humanitarian and community-centred engineering throughout studies. Student feedback has been positive, and some students can see the strong link between these education initiatives and the content of the core engineering courses.

KEYWORDS
Community-Centred Engineering, Humanitarian Engineering, Service Learning.

Introduction

Since the early 2000's there has been a rapid and significant increase in community-centred and humanitarian engineering course offerings at universities throughout the developed world. This has been driven by a number of factors, across universities, professional associations and engineering practice. Changes to engineering competencies set by professional accreditation bodies have placed a greater emphasis on engineering skills involving communication, ethics, sustainability and contextual factors (Engineers Australia 2013, Shuman et al 2005). This is reflective of changes in engineering practice, with engineering increasingly being a global activity. Design teams and cycles, supply chains and manufacturing are conducted on an international scale, driven by factors like cost, resource availability and emerging markets (Bourn and Neal 2008 and UNESCO 2010). These are balanced by a renewed focus on sustainable development in recognition of potential resource shortages, global challenges like climate change, and the need for an understanding of sustainability in both environmental and social terms (Bourn and Neal 2008 and UNESCO 2010).

Over the same period there has been a significant increase in engineering and technology related organisations with a humanitarian or specific sustainability focus. Independent Engineers Without Borders (EWB) organisations have started in many countries over the last 15 years, such as EWB Canada (founded in 2000), EWB UK (2001), EWB USA (2002), EWB Australia (2003) and EWB New Zealand (2008) to operate alongside more established EWB organisations such as Ingenieurs Sans Frontiers France (1982). In parallel, organisations such as Engineers for a Sustainable World (ESW, 2001) and Engineering for Change (EfC, 2009) have highlighted the role of technology in sustainable development. Many of these organisations were founded by engineering students, reflecting a strong student interest in the role of engineering and technology within the modern world and the impacts, both positive and negative, they can have on sustainable and equitable human development (Lucena and Schneider 2008).

These drivers have led many universities to incorporate some form of global, humanitarian, community-centred or sustainable development initiatives into their undergraduate engineering programs. These can typically be mapped to engineering competencies around contextual and global factors affecting engineering, and awareness of sustainable development and ethical principles (such as those captured in ABET outcomes 3c, 3f and 3h (Felder and Brent 2003) and EA stage 1 elements 1.5, 1.6 and 3.1 (Engineers Australia 2013)). These curriculum initiatives range from one-off introductory or guest lectures through to entire degree programs. Many of these take the form, or incorporate an element, of service learning experience with students working with an identified community or community-based organisation on a specific project (Bielefeldt et al 2009 and Schneider et al 2009).

International service learning opportunities, where students typically undertake a project in a developing country, are now widespread, particularly in the US. Some examples of service learning focused initiatives or courses are:

- Design for a Sustainable World at Stanford University (Bischel and Sundstrom 2011)
- Engineering Applications for Society at the University of Pittsburgh (Budny and Gradoville 2011)
- Humanitarian Engineering service-learning program at the Ohio State University (Simon et al 2012)

Larger programs that provide multiple service-learning experiences to students across their studies have been established including:

- EPICS at Purdue University (Coyle et al, 2005)
- SPLICE at University of Massachusetts Lowell (Duffy, 2008)

A small number of institutions build on these experiences to provide dedicated coursework in addition to service learning, leading to certificate programs such as named degrees or minors. Examples are:

- Engineering for Developing Communities at University of Colorado Boulder (Amadei and Wallace 2009)
- Humanitarian Engineering modules in the undergraduate engineering program at Coventry University (Hill and Miles 2012 and Coventry University 2014)
- BEng Humanitarian Engineering at University of Wales Trinity Saint David (UWTSD 2014)

The impacts of such programs and opportunities for students have been well documented. Bielefeldt et al (2009) and Budny and Gradoville (2011) report positive student experiences, including higher student motivation and learning outcomes for knowledge, skills and attitudes. Recent work, such as Schneider et al (2009) and Nieusma and Riley (2010), critically evaluates such initiatives to examine their outcomes, and in particular, who benefits most from the experiences, who contributes, and who takes on the greatest level of risk. Vandersteen et al (2009) concluded that for many global engineering education experiences, it is the student, typically from a developed country, who benefits most in terms of expanding their experience, skills and knowledge. The communities they work 'with' often contribute the most in terms of providing their time, knowledge and experience, and do so without a similar defined outcome.

The term 'humanitarian engineering' itself is also discussed. Hill and Miles (2012) provide a summary of definitions from existing literature before surveying university students for their understanding of the term. They conclude that "the only thing that is clear is that there is no clear definition agreed." while Greet (2014) proposes two definitions, one drawn from Engineers Australia (EA) given during the Year of Humanitarian Engineering in 2011 the second from the Colorado School of Mines in the USA. A discussion of definitions and interpretations of humanitarian engineering is beyond the scope of this paper, but it will be taken to cover engineering as part of community development, emergency response or working with vulnerable groups, based on their self-identified needs or following a request for support.

The rest of the this paper outlines how a semi-structured pathway at an Australian university was developed and implemented across a four-year engineering degree program to allow students interested in the area to explore and experience humanitarian or community-centred engineering (CCE). A number of key requirements, identified from literature and existing programs, were used to guide the development and are discussed below. The CCE program pathway is then outlined by describing the various individual initiatives for each year level. A discussion of the operation, impacts and improvements of the program is provided along with recommendations for others interested in developing similar opportunities and pathways.

Existing Initiatives and Programs Requirements

Within the engineering program at the Australian National University (ANU) a number of initiatives commenced in the late 2000's, corresponding to opportunities developed by Engineers Without Borders Australia (EWB-A) and staff and student interest in the organisation. The EWB Challenge, a first year design program initiated in 2007 by EWB-A (see Cutler et al 2011) was incorporated into the first year first semester introductory engineering course that year and has been utilised ever since. From 2008 a small number of EWB-A final year research projects have also been supported. However, for students interested in community-centred or humanitarian engineering there were a number of issues with these related but disparate initiatives. They focused basically on overseas development only (apart from one year when the EWB-A Challenge had an Indigenous Australian partner), there was understandably a significant gap between an introductory first year project and a

significant final year research project, and students were not exposed to any specific development approaches, theory or background in the rest of their studies (unless they took a dedicated non-engineering elective in the area). Following a review of literature and existing programs three key requirements were identified to provide additional student opportunities and potentially overcome these deficiencies.

The first requirement was a single initiative, either a traditional course or service learning based, was not enough to cover the breath of development and the complexities involved (Amadei and Wallace 2009 and Vandersteen et al 2009). It was clear that a range of education initiatives should be utilised to support the different learning outcomes that need to be achieved.

The second requirement was experiences must not focus only on overseas development. This is related to three points. First, the cost, risks and complexity of students being involved in overseas development work are significant (Simon et al 2012). The second builds on this and is related to the conclusions of Duffy (2008), Schneider et al (2009) and Vandersteen et al (2009). That is, often such experiences benefit the student at significant cost, direct and indirect, to the communities they work with, and often may not leave any direct lasting benefit for those communities. Finally, only being involved with international development can lead to students seeing community-centred and humanitarian engineering work as being engineering that only happens in developing countries and not an engineering skill set that can be applied more broadly or to disadvantage in their own countries. For example Budny and Gradoville (2011) reported students considered service learning in their home country (USA) as "detailed homework assignments" while international projects were "real". Liability laws in their home country meant outcomes would not be implemented there while overseas they would. This response obviously also reinforces questions in relation to who is benefitting from such projects. There needs to be a requirement to ensure all of those involved with an experience contribute and benefit appropriately according to their circumstances.

The last requirement is around partnerships. To be able to ensure appropriate student opportunities and projects, strong ongoing partnerships need to be in place, particularly to provide realistic sustainable outcomes for partners. The is highlighted repeatedly including Bielefeldt et al (2009), Bischel and Sundstrom (2011) and Tucker et al (2013).

CCE Program Pathway

Building on the key requirements identified above, additional experiences and projects were developed and incorporated into the undergraduate engineering program at ANU.

Degree Structure

The undergraduate engineering degree program at ANU is a four-year program in a single school with a common systems engineering core of seven courses which all students complete (one in first year, two each year after that). Students select from one of six specialist majors of eight courses. With additional electives, some students can complete two majors. Students complete 12 weeks' work experience in line with EA requirements and have the opportunity to complete part or all of this through competitively selected for credit internships. In order to provide an opportunity for any student interested in CCE, initiatives were incorporated into core compulsory subjects within each year as outlined below.

First Year

In the first semester Discovering Engineering course the EWB Challenge from EWB-A is used as the team project throughout the semester, as a vehicle to introduce a simplified engineering design process. In total this makes up about 40% of the assessment load. As it is designed to do, the EWB Challenge provides an introduction to sustainable community development and puts forward the concept of a humanitarian engineer. Course topics cover

the role of user requirements and engagement, appropriate technology, and technology transfer and adoption within engineering design and development. These make use of specifically designed active learning workshops to provide an engineering context to introduce these complex and multi-faceted topics. The topics are not explored in detail and students do not have the opportunity to engage with any community members directly, although engineers with experience working in the location and context of the EWB Challenge, which changes each year, provide guest lectures.

Second Year

The core courses in second year are Systems Engineering Design and Systems Engineering Analysis. These go beyond Discovering Engineering to examine and apply system engineering approaches and techniques in greater detail. A team project is utilised with students selecting from a number of topics each of which has a local client based in the surrounding region or on campus. Teams work with the client to identify requirements and performance measures, undertake preliminary design and analysis work and present their designs and recommendations back to the clients. Since 2012 projects have had an 'accessibility' theme. Projects proposed by community-based or not-for-profits organisations have included an automated entrance way for a community centre and concepts for a bike to support children with reduced motor control. A key aspect of these projects is students are required to engage directly with the client and understand their requirements.

Third Year

Community-based opportunities were incorporated into an existing for-credit internship program where students work near-full time from 6 weeks to 6 months for an organisation and while being supported by an academic mentor at the university. A number of reports and reflective items are used by the student to record their learning with respect to a number of identified elements from EA's stage 2 professional engineering competencies.

In 2013-14 four community-based internships were piloted all of which were unpaid and lasted 6 weeks. Projects were the redesign of educational kits used for accessibility training, documenting assistive device designs and two identifying options for streamlining data and process systems. These provided students with opportunities to experience the not-for-profit sector and make a valuable and significant contribution to organisations that are typically short of resources.

Since 2013, opportunities have been incorporated via a project in the Engineering Innovation course. Teams select a topic of interest and build a business plan covering a technical solution including the development of a model or prototype. A small number of teams are working on projects related to accessibility challenges and assistive devices such as door opening devices and methods.

Fourth Year

During their fourth and final year students undertake two projects, one a semester long (15-week) team project with an external client (Systems Engineering Project), and the other a two semester individual research project (Individual Project) equivalent to 25% of their work in fourth year. Students in both courses have undertaken humanitarian and community-centred engineering projects, particularly those offered through the EWB-A Undergraduate Research Program which has been operating since 2007 in various forms (see Smith et al (2009) for a description of the program). Individual research projects have included a feasibility study for solar-powered water pumping in Nepal, the development of a model for improving knowledge and technology transfer in a developing world context, and approaches for disability-inclusive development engineering. Team projects have included a cyclone shelter for remote communities and community-level biogas generation for rural Cambodia.

Extra-Curricular Activities

In addition to for credit course work students engage in community-centred work through extra-curricular activities. This may include outreach to schools via programs such as the EWB school outreach, ANU Ambassador and RoboGals programs. In later years students may be involved with short-term projects through volunteer organisations, either Australian-based or overseas. Examples have included volunteering with Seven Women Nepal and a installing a water supply system for a village in the Solomon Islands.

Discussion and Impacts

At present an evaluation of the impact of the multiple initiatives making up the semi-structured program has not been undertaken, although some feedback is available on individual initiatives. This section will outline the delivery of the program, discussion of its impacts and engagement, improvements identified and recommendations.

Implementation and Delivery

The program available to students is largely project-based work, either as an entire course or project-based components within courses. Outside the EWB Challenge in first year, student engagement is optional allowing students to try a project or be involved in a number over their studies if they have a particular interest in the area. External partner organisations with both a local and international focus have been involved. At a local level projects have been completed with five not-for-profit groups, four working with people with disabilities and the fifth with aging populations. International partners have mainly been through EWB-A and a small number of organisations that students undertaking projects already had personal involvement with.

Engagement and Benefits

Beyond the EWB Challenge in first year, involvement in CCE projects is optional. Table 1 outlines the number of projects undertaken over the last six years in each of the year levels and courses since they have become available (the figure in brackets is the approximate number of total projects in the course). As can be seen the project opportunities have increased in the last two years due to course re-structuring in second and third year to provide more project based work (such opportunities were not available pre-2013). In 2014 there are four coordinators involved with the courses highlighted, including the two authors.

Table 1: Student projects involving humanitarian or community-centred engineering topics per year for core course, with the total number of projects offered in brackets.

Level	**Second Year**		**Third Year**		**Fourth Year**	
Year	**Design**	**Analysis**	**Innovation**	**Internships**	**Individual**	**Team**
2009	n/a	n/a	n/a	n/a	6 (90)	0 (10)
2010	n/a	n/a	n/a	n/a	5 (100)	0 (10)
2011	n/a	n/a	n/a	n/a	3 (130)	1 (120
2012	n/a	n/a	n/a	n/a	3 (140)	1 (12)
2013	31 (35)	33 (35)	0 (40)	2 (40)	5 (150)	3 (15)
2014	34 (40)	37 (40)	3 (40)	2 (40)	8 (150)	1 (15)

Many of the local partners involved see outcomes from individual projects but also appreciate the long-term and systemic changes resulting from engineering students being engaged with local projects with vulnerable groups whilst studying. They see significant benefits from exposing students more widely to social problems, appreciating that learnings will be carried forward by students throughout their careers. From a student's perspective, the additional

motivation of such projects was highlighted during the community-based internships. Quotes from post-placement interviews with students included:

[S1] - *There were also new skills to be acquired. It was all very hands-on. It was good to feel a direct impact so quickly.*

[S2] - *Motivated to do work because its appreciated.*

As highlighted in Duffy (2008), Bischel and Sundstrom (2011), Paterson et al (2013) and Tucker et al (2013), strong ongoing relationships with partners are necessary to provide suitable projects and support for students. The approach here is two-fold. For projects with an international (non-Australian) focus, partnering with EWB-A and through it multiple community partners has been more effective than establishing and maintaining relationships with partners directly. This provides the long-term sustainability of relationships that is required, as EWB-A maintains these as part of their ongoing core operations.

For local projects, partnerships are being established around shared values and clearer understanding of the contextual and cultural setting (as highlighted in Tucker et al 2013). Such relationships can be better matched to curriculum opportunities and can lead to multiple projects. For example, one local partner here has identified projects offered through second year courses, third year internships and fourth year research projects.

Improvements Identified

A gap has been identified based on experiences with the projects in third and fourth year, specifically the research projects and internships. In these, students are required to apply specific approaches to engage with end-users and have a solid understanding of cross-cultural elements and development principles in general. Background in this theory has often been lacking, requiring university supervisors or mentors to provide this material to students during the early stages of their projects which takes time away from other elements.

To fill this gap a project has been approved to develop a dedicated third year humanitarian engineering course. This will provide specific skills and knowledge about appropriate approaches and theories of humanitarian engineering in its various forms. This will act as background for students wishing to undertaken more intensive projects in their third and fourth years, allowing them to apply the theory and skills developed to their projects.

Recommendations

Based on the development of the program pathway here a number of recommendations are made for other institutions or groups interested in developing similar opportunities or models. First, there needs to some coordinated effort between coordinators across different courses and year levels to ensure opportunities complement and build on each other and provide opportunities from the spectrum of community-centred and humanitarian work. As highlighted in Hills and Miles (2012) and Greet (2014) definitions and understandings of humanitarian engineering vary, reflecting the range of activities that can be involved. Having student opportunities across the range is more reflective of the humanitarian work engineers are involved with, rather than only focusing on international development for example.

Ongoing relationships with partner organisations are required which place outcomes and benefits for the external partners as a priority. Building and fostering these is generally more straight-forward with local community partners where regular ongoing engagement is easier and generally lower risk. For overseas projects, locally-based community organisations working overseas, in this case EWB-A, can be used to support relationships.

Finally, student interests and extra-curricular activities should be built upon. This gives a direct link to student demand and can provide an additional level of resources, relationship management and enthusiasm, which is important. However as with most student groups, interest can vary from year-to-year and hence faculties should also provide active support to student groups to maintain a level of sustainability.

Future Work

There are two key aspects of future work being planned and undertaken, the first around evaluation of initiatives and the second on developing dedicated coursework support. A detailed evaluation of the program as a whole needs to be undertaken similar to those of Bielefeldt et al (2009), Bischel and Sundstrom (2011), Hill and Miles (2012) and Tucker et al (2013). As the opportunities across all year levels have been in place for two years, students who may have been involved in multiple initiatives will be in their fourth year in 2015. This presents an opportunity to investigate the combined impact of initiatives before students graduate. This will examine students' understanding of humanitarian engineering and specific outcomes they feel they have gained through engagement in the activities here. As optional CCE elements are being provided through the compulsory core a wider evaluation can be undertaken to compare students engaging in CCE with students with other interests.

As highlighted, a dedicated third year humanitarian engineering course has been approved, with an initial delivery planned for winter 2015. The impact of this of this course within the program will be investigated as part of the evaluation described in the previous paragraph. In addition, based on recent projects focusing on accessibility, a dedicated learning program with a focus on assistive technology is being established involving a number of institutions offering different degrees across technology and design. This will provide a more seamless way for individuals and groups to engage with educational providers and students.

Conclusion

Over the past two years a semi-structured pathway allowing students to explore humanitarian and community-centred engineering in each of the four years of an engineering degree program has been developed. This has focused on optional service-learning style projects within core compulsory courses and allowed students to examine a number of aspects of humanitarian engineering. Although a formal evaluation has not been undertaken, early data seems to indicate an increase in student interest in such projects and positive feedback from both students and external partners. The existing initiatives will be complemented by a dedicated third year humanitarian engineering course from 2015.

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