Lessons learned from the design and delivery of a new major in Humanitarian Engineering

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CONTEXT

Many engineering students are socially conscious and motivated to use their engineering degrees to help tackle global problems, including those caused by poverty and natural disasters. There is a gap in the standard teaching curriculum for these students and therefore we developed a major in Humanitarian Engineering to provide initial knowledge and skills in the sector. Graduates with a Humanitarian Engineering skill set are needed in the private, public and not-for-profit sectors to apply methods of their respective engineering disciplines to meet the needs of communities globally in a sustainable and appropriate manner.

PURPOSE

In collaboration with industry, we designed and delivered a Humanitarian Engineering Major to undergraduate engineers to test the scope, achieve desirable learning outcomes and assessed student demand for this new type of education.

APPROACH

The term Humanitarian Engineering is not well defined from an educational perspective, hence the scope of the Major had to be discussed in the first instance. An industry advisory panel and a network of universities was formed to gain input on the learning outcomes and desirable graduate attributes. The Major was designed around four subjects totalling 24 units of credit, for third and fourth year undergraduates from all engineering streams. The first unit of study taught an initial understanding of humanitarian engineering, utilising lecturers and guest seminars. This subject was a prerequisite to the second subject focused on engineering for sustainability. Importantly, the third subject was a two-week fieldwork subject, where students undertook a program of activities in either a developing country or an Indigenous community. To widen the breadth of students' knowledge, a fourth subject offered choices in global health, disaster management, international project management and understanding of Southeast Asia. The fieldwork subjects were delivered first, commencing in summer of 2016. The first classroom lecture-based course was taught in the second semester of 2017.

RESULTS

The scope of Humanitarian Engineering was taken to include engineering in developing countries for development purposes, during all stages of disasters, in remote communities and Indigenous communities. Despite the low proportion of women among engineering students, there is an equal representation of gender in the program. Unit of study evaluations have returned with higher than faculty average scores and comments from several students suggested that 'this is the career path they want to take'. More detailed unit of study surveys will be undertaken to determine if the content of all the four subjects is achieving the desired learning outcomes. Further, the input of the industry advisory panel and other universities will help shape the definition of Humanitarian Engineering education. There are some informed assumptions about the contexts in which humanitarian engineers work and in-time this might prove too narrow.

CONCLUSIONS

Based on consultation with industry partners and initial experience, we suggest that subjects in Humanitarian Engineering can fill a gap in the current engineering curriculum and attract a new type of engineering student. However, more work is needed to agree on the scope of Humanitarian Engineering in the Australian higher education context. The co-ordination with industry and other universities will be critical to consolidating the educational outcomes.

KEYWORDS: humanitarian engineering, global engineering, new curriculum, sustainability

Introduction

Engineers are needed to direct meet the targets of a number of Sustainable Development Goals (SDG) (United Nations 2015):

- Goal 3: Good health and well-being needs Biomedical Engineers
- Goal 6: Clean water and sanitation needs Civil and Chemical Engineers
- Goal 7: Affordable and clean energy needs Electrical Engineers
- Goal 9; Industry, innovation and infrastructure needs Civil and Mechanical Engineers
- Goal 11: Sustainable cities and communities needs all types of engineers
- Goal 12: Responsible consumption and production needs Material Engineers
- Goal 13: Climate action needs Environmental Engineers

A new generation of engineers need to be trained to build a more sustainable and equitable planet (Amedei *et al.* 2010). There is a growing number of socially conscious engineering students who want to use their engineering degree to improve the world, both at home and abroad. However, the typical engineering curriculum does little to support an engineer to have a humanitarian-focused career (Passino 2009). The perceived lack of concern in engineering for humanitarian issues might be what some highly motivated high school students, especially women, are missing and therefore choose other specializations (Nillson 2015). Engineering fields that have clearly articulated their links to enhancing human well-being, such as Biomedical Engineering at the University of Sydney, attract the highest number of female students.

The United States has a number of well-established humanitarian engineering curriculums where the engineering students learns the engineering basics but also history, politics, economics, sociology and culture (Brown *et al.* 2014). There are an increasing number of universities in Australia undertaking curriculum development in humanitarian engineering. The Humanitarian Engineering Education Network of Australasia (HEENA) was formed in 2017 to bring together these universities.

Pedagogical objectives

The Faculty of Engineering and IT at the University of Sydney has recognized that it must better cater to students concerned about the most pressing global issues to educate engineers who can improve human lives on a large scale. Therefore, a new major in Humanitarian Engineering was proposed. The main pedagogical objectives are that the new major in humanitarian engineering at the University of Sydney should educate students in:

- The specific contexts of humanitarian engineering applied to developing countries, disaster relief and remote locations
- How engineers are critically needed to meet the Sustainable Development Goals
- Specific skills needed to work as a humanitarian engineer
- Real-life cross-cultural fieldwork
- Career pathways in humanitarian engineering

Curriculum design

The capacities outlined above clearly cannot be gained only inside classrooms. The new curriculum was designed around core elements that enable students to directly learn from people living in developing countries and remote communities by interacting with them in other than tourism or volunteer work context. To maximize learning from such practical experience the curriculum contains project-based work directly connected to theoretical content provided in the classroom courses.

Motivation and context

The institutional environment was supportive. One of the main goals of the University stated in its Strategic Plan was to "expand and diversify opportunities for students to develop as global citizens". The Faculty of Engineering and IT was also aiming to attract high school students with humanitarian ideals who would not originally connect these with engineering. A young student who is about to decide her life direction may be asking herself: "Why would I would I work on male-dominated construction sites in Sydney, when there are so many more important problems in the world?" The goal was to attract such students, equip them with skills that make them highly attractive to a whole range of employers, and expand their horizons by an intensive exposure to unfamiliar resource-constrained communities overseas and in remote rural Australia.

The decision to provide this new type of education coincided with the development of a new modular structure of Majors in the Faculty, which allowed for a coherent set of common generalist units of study to be added as a Major on top of the core of the diverse curricula of the respective schools within the faculty. It was recognized as an important goal of the major to bring students from diverse disciplines and enable them to enrich their technical expertise by learning how to apply it in unfamiliar and resource-constrained contexts. Therefore, the goal of the Major was to add breadth and understanding of practical applications in the final years of the undergraduate curricula. The Major is not standalone—its impact is in the combination with other technical parts of engineering curriculum that all students needs to master.

Industry advisory panel

Research to inform the design of the Major commenced in 2013 with the formation of an industry advisory panel. The panel consisted of 16 people representing the private sector engineering consultancy firms, large multinational organisations, non-government organisations and higher education. The scope and purpose of humanitarian engineering education was discussed within the context of industry need. During the meeting, attendees were asked to rank stated skill sets important for a humanitarian engineer, and encouraged to add and rank additional skill sets. Some of these skill sets were related and have been compiled into groups. The rankings were normalised and added for each skill set to produce an aggregate score (Table 1). The higher the score, the greater importance is attributed to the skill set. Interestingly the skills sets that were most highly rated were linked to project management, design and communication. These skill-sets needs were the foundation on which to design the curriculum for the Major.

Table 1. Industry panel ranking of the top skills sets important for a humanitarian engineer

Skill set	Score
Behaviour/ethics/working with local culture and in teams, Communications	37
Project Management, Complex systems awareness & Safety and risk	35
Dealing with public monies/policies Stakeholder consultation & participation & Project Design	27
Sustainable outcomes/capacity building/training Sustainable development - cultural, econ, social, environ Environmental Engineering	25

Market survey

The Faculty has commissioned a market survey of Year 11 and Year 12 students at several high schools in Sydney who considered studying engineering at a university. The survey also included in-depth interviews of industry experts and focus groups of undergraduate engineering students at three universities.

The findings were that Humanitarian Engineering could provide a highly distinct new educational direction and fit well with the University's reputation for social contribution. The survey identified that such a course could draw students from medicine, humanities, and science.

However, some informants were concerned about the limited application of such specialization for future work and associated "humanitarian" only with aid and disaster-relief overseas, which they found limiting. Humanitarian Engineering was less attractive for international students than for domestic students.

The recommendations of the study was that the Major should emphasise development and capacity building, rather than disaster relief overseas and that it should include domestic components leading to broader work opportunities in Australia. The study also recommended to find new partners for this Major, instead of relying on traditional partners in the construction sector, to demonstrate the new pathways that the Major opens. In summary, Humanitarian Engineering should not be simplistically framed as "engineering for poor people who cannot help themselves".

The discussions of the focus of the Major were accompanied with intensive discussions of what it should be called. In addition to the reservations regarding the narrow associations of the term "humanitarian" with disaster relief overseas, several internal and external stakeholders found the term too "missionary", "colonial", "imperial", and "overbearing". Also, there was a concern stemming from the market survey about general employers' perceptions about students with a "humanitarian" major on their diploma.

Another survey was conducted among students within the Faculty. 411 students responded to the question: "Imagine that you are a high school student selecting your future specialization and that streams with the following names are offered by the School of Civil Engineering. Considering your interests, your future career, and everything else together, would you think of choosing any of the streams listed below? Assume that you do not know their content, so you have to guess only from their names. The options provided and the results were: (1) "Global Engineering" (31%), (2) "Development Engineering" (27%), (3) "Humanitarian Engineering" (22%), and "No such stream would attract me" (21%).

The reason why the Faculty chose "Humanitarian Engineering" over "Global Engineering", which was more popular among students, was partly because the Faculty wanted to emphasize the positive societal impact as the main focus of the Major. The term "global" might not sound appropriate for projects in Australian remote communities – one of the planned target areas of the Major. (Although, it was recognized that it is possible to work on pressing issues of global importance domestically.) Moreover, the term Humanitarian Engineering was used by Engineers without Borders (although with reservations), who were identified as an important future partner for the Major. Another reason why a name which implies a focus on the human condition as compared to more normatively neutral "global" was selected, was that the term was used already by some universities overseas.

Survey of programs at universities overseas

A survey of existing programs in other countries found that some academics in the USA tend to use the term "Humanitarian Engineering" for minors and majors aimed at application of engineering in low-income contexts. Global Engineering majors and minor tend to focus more on preparing engineers for work outside of their country of origin and unfamiliar cultures but without the connotations of "helping impoverished people".

The survey did not find entire Bachelor degrees of Humanitarian Engineering but sets of units under Humanitarian Engineering label at Penn State University (Humanitarian Engineering and Social Entrepreneurship), Colorado School of Mines (Minor in Humanitarian Engineering), The Ohio State University (Humanitarian Engineering Center – including postgraduate opportunities), Massachusetts Institute of Technology (MIT Humanitarian Response Lab), and Oregon State University (Humanitarian Engineering, Science and Technology).

Some American universities used other labels for programs with a similar focus, such as Arizona State University (Global Resolve Program), University of Colorado, Boulder (Mortesen Center for Engineering in Developing Communities), and Purdue University (Global Engineering Program).

Defining the scope

As seen above, different institutions define Humanitarian Engineering in different ways. We adopted an approach that we judged appropriate for the context of an Australian university: "*Humanitarian Engineering is the application of engineering to meet the needs of communities globally; while maintaining a focus on appropriateness and sustainability".*

Humanitarian engineers are skilled engineers from all disciplines, who apply their skills and knowledge to challenges present in:

- Developing countries
- During all stages of disaster
- Indigenous communities
- Remote communities
- Global sustainability

The lesson learned from the scope of the Major was perhaps it was too broad and overlapped with components of subjects in sustainable engineering, environmental engineering and international project management. To de-conflict these overlaps the focus for the Major was emphasised to be in developmental contexts.

Designing the curriculum

When designing the curriculum it was firstly decided that fieldwork overseas and in remote communities in Australia will be a core component of the Major. Secondly, it was decided that the Major will include a unit that will be focus on sharing of experience of guest speakers from the industry. We found that our industrial partners and supporters were willing to contribute to lectures and this was seen also as an opportunity to strengthen the links between the Major and the industry. Experienced practitioners can explain to the students how to prepare for global careers, especially for work in developing countries and most demanding contexts such as disaster recovery. The units should bring together students from diverse disciplines and by letting them collaborate over two years in Sydney and overseas the intention was to develop a cohesive community and long-lasting relationships among students interested in contributing their engineering knowledge to worthy causes.

The whole structure of the Major was designed not to exclude any engineering student from any specialization by prerequisites. The selection of students to the Major would be only in terms of achievements, fit, and motivation not their specialization. The selection takes place during enrolment of the students to the fieldwork unit of study, which is an essential element of the Major. To assure students' safety in the field, the number of students acceptable to this fieldwork unit is determined by the capacity of local partners in the fieldwork location each year. This logistic necessity justified the decision not to allow some students to enrol in to the unit and therefore prevent them from completing the Major – a useful option to have for a Major in engineering with no formal prerequisites. A unit of study with no requirement in terms of quantitative skills and very open-ended outputs might mistakenly attract students who seek an easy credit and lead to problems in the field. This element of exclusivity was expected to attract top students and attract the attention of employers.

Specifically, the Major consists of four full subjects (6 units of credit each) chose from component A, B, C and D (Table 2). Then two full subjects in applied research from component E. Importantly the fieldwork component (C) was included as a critical skill-set development unit based in real-world experiences. This fieldwork was supported by Australian Government Funding through the New Colombo Plan Scheme.

Table 2. Structure of the Humanitarian Engineering Major for 36 units of credit.

	Subjects	Details
A	CIVL3310 Humanitarian Engineering	3rd year elective, introduction
B	CIVL5330 Engineering for sustainable development	4th year elective, greater depth
C	CIVL5330 Global Engineering Fieldwork, or SLIC 3000 or SLIC 4000 Service Learning Indigenous Communities	Two-week domestic or international fieldwork (winter and summer break).
D	ASNS2665 Understanding Southeast Asia, or PMGT3857 International Project Management EDUF3026 Global Poverty and Education ITLS6007 Disaster Relief Operations HSBH3009 International Health	Breadth subjects delivered outside of the school and can be taken at anytime
E	CIVL4022 Thesis A CIVL4023 Thesis B	Final year thesis related

Content of CIVL3310 Humanitarian Engineering

This course explores the role of engineers in disaster recovery and humanitarian assistance in the most vulnerable communities. The unit of study is concerned with ways in which engineers can help such communities deal with sudden natural or man-made shocks, before or after they occur. The students develop an understanding of the linkages between life-supporting infrastructures, well-being of community and their vulnerability to disasters. Through a set of case studies and lectures provided by guest speakers with experience of humanitarian work and international development projects, the unit raises and explores a number of questions. How can the effectiveness of "humanitarian interventions" be measured, and what are the most important determinants of effectiveness? Who makes decisions on such interventions and are they a human right? What is the role of diverse stakeholders in response to crises in vulnerable settings? How to communicate with them and cooperate with them while upholding high ethical standards and at the same time respecting their culture and the ways things are done locally? How to work with and for non-governmental and non-profit organizations? How to coordinate large international programs to respond to humanitarian crises? How to combine technological and social approaches when addressing vulnerabilities in socio-technical systems? Importantly, what role engineers currently play and should ideally play in implementing humanitarian interventions?

Content of CIVL5330 Global Engineering Fieldwork

Global engineering field work is a project-based interdisciplinary intensive unit of study in which students will explore how to utilize the knowledge gained in classroom courses to implement engineering projects in low-capacity contexts. The students gain practical experience working in teams in a safe and supervised environment by participating in real engineering projects that aim to improve living conditions of inhabitants of vulnerable communities in Australia and overseas. The projects stimulate the students' awareness of global social problems and the passion to tackle them. The students practice to communicate, develop trust, and negotiate with the local stakeholders and cooperate with the local governmental units, the private sector, and the civil society to explore the root causes of the uncovered problems. To successfully communicate their ideas, the students may need to use other languages than English. They search for potential engineering approaches to the reinvigoration of local communities and aim to achieve the best outcomes with limited public or private investments. They learn in practice that a solution to complex global social problems cannot be found through any engineering discipline alone but rather through cooperation and consultation with experts from other fields, the directly affected stakeholders, and the general public.

Content of CIVL5330 Engineering for sustainable development

The question of this course is how to build resilient cities and communities that will enable in the future inclusive social and economic growth within the planetary resource boundaries? This course is about engineering for long-term improvement of the human condition. This unit will introduce the concept of sustainable development and the role of engineering in tackling global problems. It explores the challenges encountered in running engineering projects and programs that are socially inclusive, environmentally sustainable, while contributing to economic development. The questions tackled in the unit include the following: What is development and how to measure it? What are the causes of poverty? How to build sustainable cities and rural communities that provide physical and food security to their inhabitants and enable them healthy lives? How to achieve equitable access to water and health services globally? How can improved means of public transport and information-communication technologies contribute to the social inclusion in urban and rural communities? How can engineering infrastructure and new technologies contribute to poverty reduction and sustainable growth locally and globally?

Learning outcomes

The learning outcomes were based on the skill-sets identified by the industry advisory panel

- Apply specialised engineering knowledge to propose improvements in the delivery of humanitarian and developmental projects.
- Ability to identify human issues and local constraints and design appropriate solutions.
- Ability to analyse the process of implementing an engineering solution and the ability to create better project outcomes by improving process.
- Experience in the use of assessment tools and techniques to guage community needs and/or the long-term effectiveness of develoment and response programs.
- Challenges faced by conflicting customs and competing outcomes will present dilemmas which are resolved by reference to personal accountability hierarchies.

Reference texts

A survey of reference texts was undertaken by reviewing any titles with the reference to humanitarian engineering or sustainable engineering. The results were mixed with some sustainability texts being too general in nature while some humanitarian texts focused entirely on humanitarian disaster response. After review a reference texts from Ohio State University, USA (Passino 2016), an African political economist (Moyo 2009) and The Sphere Project Handbook (The Sphere Project 2011) were selected.

Curriculum delivery

Fieldwork delivery

We needed to find a systematic, safe, and affordable way to bring a large number of students to the projects in remote communities and overseas, enable them to collaborate with local stakeholders, and at the same time deliver academic content considered worthy of final years of Bachelor of Engineering at a research-intensive university.

Partnering with Engineers without Borders and their experienced facilitators enabled to bring a large number of students to the field without prohibitive time demands on logistics management by the academic supervisors. The flip side of partnering with a 3rd party provider that runs standardised centralized programs is a partial loss of control over the management of the program and the necessity to make some compromises in terms of academic content. More customizations of the program means higher cost that need to born by someone.

The cost for our domestic students was offset by the availability of New Colombo Plan funding provided by the Department of Foreign Affairs and Trade provided by the Australian Government. The unavailability of this funding for international students raised issues of equity and eventually the School of Civil Engineering at the University of Sydney agreed to subsidise the participation cost of a limited number of highly-qualified international students each year. The question of financial sustainability will arise when New Colombo Plan funding cedes. Fieldwork will always be more costly then classroom units and subsidies provided by the University will be necessary to deliver the desired outcomes at the desired scale required by the University Strategic Plan.

In addition to the logistics in the field that is facilitated by a third party, as compared to a classroom unit of study, field work unit of study requires more administrative support before the departure. The School appointed an administrative staff member on two days per week basis to coordinate the students. Institutions that want to run similar programs should allocate necessary resources for such support. Another requirement for successful fieldwork is high academic staff to student ratio. We realized that it is optimal to have approximately one tutor per 15 students in addition to academic oversight and resources need to be allocated to this as well.

The results were good and the fieldwork proved popular among students. The applications for fieldwork for were greater than the number of places available. The actual enrolment numbers are in Table 3.

Delivery of classroom units

The first lecture subject was delivered in Semester 2 2017 with 36 enrolled students. Based on the number undergraduates and thoses that have available electives to chose majors it is estimated that the major will reach 70 – 90 students per year cohort.

Table 3. Delivery of humanitarian engineering curriculum

Unit	Delivered	Student enrolments
CIVL5330 Global Engineering Fieldwork	Summer session December 2016 – India	19
CIVL5330 Global Engineering Fieldwork	Winter session July 2017 – India	34
CIVL3310 Humanitarian Engineering	Semester 2 2017	36

Student motivation

For the lecture based subject students were asked why they had chosen the subject. Each student replied with three words. Out of the 80 responses the most frequently mentioned reason was ‘interest’ (nine counts) followed by ‘impact’ (six counts) (Figure 1). Other frequently mentioned reasons were ‘different’, ‘altruism’, ‘career’ and ‘global’ (four counts each). The wordcloud aligns with the assessment that socially aware students who want to make an impact with their degree were chosing the humanitarian engineering subject. There was reports second hand from some students that other students who were interested in the subject but had not chosen the unit because they were worried that there would be a large number of essays to write and they were concerned about their writing skills.

Figure 1. Word cloud generated from student responses to the question ‘Why did you choose to study humanitarian engineering?’

Fieldwork learning outcomes

Fieldwork subjects delivered in India and Samoa were each a two-week program supported by Engineers without Borders and based on their Design Summit program. The program has three stages of 4 days each: cultural orientation and human centred design workshops, homestay and then design and then final presentations.

For this subject additional content was introduced to students through a pre-departure workshop and assessment. The assessment consisted of: pre-departure assignment focused on the SDGs, in-country participation mark, group presentation and report video and an individual report and personal reflection.

Students were free to identify design challenges and come up with design ideas that included: water and wastewater, construction and response disater risk reduction and agricultural post processing.

Figure 2. Fieldwork pictures taken in India in December 2016 (L) and Samoa in July 2017 (R)

Student evaluation and feedback

The formal unit of study evaluations for summer and winter units of study scored satisfaction ratings above the school average (4.3 and 4.6 respectively, as compared to 3.9). Comments from the students were that the fieldwork had allowed them to apply their engineering skills to real-world problems. Many realised different career paths are available to humanitarian engineers. Students also reflected that the immersive overseas fieldwork experience improved their ability to work in teams and in cross-cultural settings. The students' experience of the domestic fieldwork was similarly positive. One student wrote that participating in the project was the most useful and important thing she has done in her life.

The Major seems to positively impact student recruitment already. The Faculty offers Leadership Scholarships to the brightest high school students. In the last round of applications, approximately 10% of applicants specifically stated that they are applying to the Faculty because of the Major and a number of other students mentioned their general humanitarian interests.

Remaining challenges

One challenge of such interdisciplinary initiative is working across administrative boundaries within the institution. Every engineering School within the Faculty needs to respect their strict accreditation requirements and ensure that each unit of study complies with competency levels defined in each School. It is challenging both in terms of time and conditions for learning outcomes to fit into these diverse and highly-demanding curricula units of study that cut across Schools.

Next, we need to ensure that once we start welcoming students who entered the Faculty only because of Humanitarian Engineering that they do not lose their motivation before they get the opportunity to immerse themselves in real projects. Embedding in the early years of the curriculum more of content that is attractive to such students will be necessary.

Finally, in addition to the collective fieldwork units, a remaining challenge is to develop sufficient opportunities and resources for Humanitarian Engineering students' final projects and theses.

Conclusions

Engineering should be about making lives better. We need to expand our degree programs to provide our students who want to improve the world with an understanding of the needs of people who are without adequate access to energy, shelter, water, and sanitation. The Humanitarian Engineering major is a response to the global need to educate engineers to meet the SDGs. We hope that as word spreads about the Major that more like-minded students will enrol. Evidence from the most recent high school students' scholarship applications suggest so. The purpose of this paper was to share within HEENA network and beyond our experience in developing the major and the challenges encountered in different stages of the process. We hope this will contribute to further development of Humanitarian Engineering education in Australia and overseas.

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