Design and Evaluation of a Humanitarian Engineering Education Pathway

Jeremy Ingle Smith

September 2019

A thesis submitted for the degree of Doctor of Philosophy

of the Australian National University

I declare that the work in this thesis is entirely my own and that to the best of my knowledge it does not contain any materials previously published or written by another person except where otherwise indicated.

Jeremy Smith

September 2019

Dedication

To Mum, 1935 - 2011

for making our past

To Sophie, 2011 -

for shaping the future

Acknowledgements

I would first like to acknowledge the traditional custodians of the land where this work took place and the ANU how sits. While the 3 ½ years of the thesis was a long time for me, I simply cannot comprehend the thousands of years of knowledge embedded in land around the ANU and my home.

Although this thesis commenced in 2015, its genesis goes back further and there are some significant figures I would like to acknowledge who set me on this journey. Most significantly Lizzie Brown, who encouraged, inspired and supported me to get more involved with EWB, be creative, and look to influence and make change. Without her generosity and enthusiasm this research would never have started. Also significant to this study, both from my early days with EWB and again during research and writing is Anh Tran. I can still remember the moment Anh asked if I would be interested in taking on a paid role with EWB - it was one of the most exciting and amazing moments of my life. Distance has been a challenge but I hope we can finds ways to continue to work together Thanks also to Dan Loden, which must count as of the most productive and enjoyable working relationships of my career. I never realised just how much two people could talk about one thing (humanitarian engineering education). Dan - this is the volcano! Also from my early days at EWB it was amazing, and lots of fun, working with people including Amanda Cahill, Beth Davies, Todd Houstein, and Kim Axworhty.

There have been more EWB people involved during the research in this thesis. A big thanks to Jenny Turner and Nick Brown. Working together on curriculum development and our OLT grant was so motivating and enjoyable, and to see the impact it has had has been very rewarding. Thanks also for getting involved in the publications here, and very much looking forward to working together for many years to come. Thanks also to all those involved with EWB's education program, Julian O'Shea, Joli Price, Alison Stoakely and recently George Goddard and Sam Perkins. A particular shout-out to my fellow EWB Undergraduate Research Program coordinators Julian, Nick and George, pretty amazing to have been at the start of a chain that continues more than 10 years later.

Although many have been mentioned above, acknowledgement and thanks to all my co-authors involved in publications here. To work with so many people over the course of the thesis has not only made the work a higher quality through insightful comments and suggestions, but much more enjoyable. The thesis has been collaborative and social the whole way through, which has made it a particularly enjoyable experience.

I would like to acknowledge and thank the other external partners who have engaged with us and provided opportunities to students. In particular Abundant Water and Sunny Forsyth, Enable Development and Huy Nguyen, and TADACT. Without these and other partners and individuals we would not be able to deliver the programs in this work.

At the ANU, I'd like to start with my PhD supervisor Paul Compston, for giving me the opportunity to undertake this work as a PhD, making sure all the mechanics and support were in place, and seeing it through to a (hopefully) successful completion. To my other panel members Chris Browne, Huy and Lesley Jolly, I did not work with you anywhere near as much as I hoped or wanted, which entirely my doing, and I am sure the work would have been enhanced with more of your input.

An acknowledge and thanks to Kim Blackmore, who helped foster and support my initial interests in education as an area of practice, and provided numerous opportunities to explore my teaching practice. Those experiences and skills led directly to the development of the education programs and initiatives in this work. Was great to have a cameo again at the end of the research as well.

I want to thank other parts of the ANU for getting this work to happen. On the PhD side, the HDR team in CECS have always been helpful and responsive and made sure things happened when they needed to. I did not have any major issues during my candidature and that is in a large part down to them. The various PARSA writing workshops have also been immensely helpful so thanks to the facilitators who make those sessions happen. More broadly at the ANU, I want to thank the teams that helped get the education development and delivery here done. In particular, CECS Student Services, specifically Paul Melloy and Natalie Young, who have always supported my ideas in this area and made sure they were available to students, and the numerous members of the CECS Marketing Team. The CHELT Promoting Excellence team have been great with not only awards, prizes and grants, but being supportive of education innovation and research in general.

As the person from the ANU most involved in my humanitarian engineering journey, from almost the very beginning, a huge acknowledgement and thanks to Chris Browne. From being the most creative, independent and organised honours student, through an EWB volunteer intern and running outreach, to an academic colleague and panel member, your contributions have been significant, insightful and ongoing. It is unfortunately (but understandable) we could not see many of the ideas through to the end (not that there is really ever an end) but it was great to be able to work together closely for so long.

Finally from the ANU I must acknowledge all the students who have been involved with humanitarian engineering and the research here. Going back to the early days, the outcomes achieved would not have occurred without student interest, motivation and drive. From the first honours students, Natasha Crossman and Kris Robinson, through members of the EWB ACT Chapter, to early adopters of the education innovations, there have been so many. Some who I would like to acknowledge for their significant engagement and involvement are Aadrik Duynhoven, Gail Sutton, Rachel Hogan, Hamza Bendemra, Cameron Nelson, Sam Palmer, Rebecca Watts, Darien Colbeck, and Emily Gentilini (apologies to all the others I did not name). Although not specifically humanitarian engineering, a big thanks to Sam Cheah, for driving so much change and positive impact on her own. To students who completed surveys (of which there a number) and took part in interviews, thanks for your time and input.

Lastly, to my family. To Dad, Sarah, Chris and Mitchell for always supporting and being interested in my involvement with humanitarian engineering and coping with, and covering, any absences while travelling, researching or writing, it has meant a lot. Your support and understanding has been a constant in my life from which I could build.

Finally my amazing partner Cally and our wonderful daughter Sophie. I hope this has not had too much an impact on weekends, playing games, holidays and spending time in the garden. But the deepest thanks and appreciation for letting me pursue not just this thesis but all my work in this space to follow my passion. That said, I am looking forward to playing games, reading books, harvesting produce, knocking down walls, building garden beds, making passata, filling our larder with abundance and our home with creativity and colour, laughter and love.

Abstract

This thesis by compilation investigates the design, delivery and student outcomes from the first undergraduate Humanitarian Engineering pathway in Australia. The non-award pathway consists of opportunities across all four years of an engineering degree utilising curriculum approaches including project-based learning, study-abroad, intensive mode teaching, and service-learning. This built upon the systems engineering core of the degree where isolated assignments and project topics were available in compulsory courses before the research commenced. The first part of the research completed the pathway by designing and delivering a dedicated elective course, Engineering for a Humanitarian Context (EfaHC). In parallel, mechanisms for immersive Humanitarian Engineering experiences to be integrated into students' programs were finalised and partnerships with external groups established.

To investigate students engaging with the pathway and the outcomes they gained, a concurrent nested mixed-methods approach was adopted. This collected quantitative and qualitative data from before and after dedicated Humanitarian Engineering education experiences. A baseline survey of the entire 3rd and 4th year engineering cohort was collected, to allow comparisons between the overall student body and those undertaking Humanitarian Engineering experiences. Interviews were conducted with graduates within three months of graduation who had completed two or more optional Humanitarian Engineering experiences, to explore their motivations, engagement, challenges and outcomes.

From quantitative surveys it was found 8-12% of the overall engineering cohort was engaging in optional Humanitarian Engineering experiences. These students had characteristics that differed from the overall cohort, being more likely to be domestic, have English as a first language, study a double degree, and be female. They were more likely to have a wider range of experiences as a student including engineering work experience, volunteer work, involvement in student clubs and societies, and involvement in community work before university. Engagement with Humanitarian Engineering was motivated by opportunities to apply existing engineering knowledge, have an international experience, and utilise engineering to "help". Such students were also motivated to have career paths in humanitarian, development or community-based areas.

Combining quantitative and qualitative results, seven outcome areas were found where Humanitarian Engineering experiences were providing benefits for students and graduates:

employability; tools, processes and skills; personal beliefs; social and enjoyment; motivations; understanding of Humanitarian Engineering; and engineering practice. It was found that engaging with Humanitarian Engineering and the curriculum approaches utilised was creating graduates with discipline depth as well as greater appreciation of, and experience with, professional skills and the application of engineering.

These findings shaped a new Minor in Humanitarian Engineering award program at the institution, which seeks to build a holistic program for students. It draws courses from other disciplines and fields, including international development, resource management, natural hazards, and domestic disadvantage. The research has helped shape the growth of Humanitarian Engineering education in Australia. The model of the Engineering for a Humanitarian Context course and its inclusion of international experiences has been adopted by other universities in Australasia. The research informed a national position statement for the further growth of Humanitarian Engineering education in Australia through dialogue engaging universities, the peak professional body, and range of community and for-purpose groups.

Table of Contents[1]

[1] Each publication is included in its "as published" format, including page numbers and figure and table numbers. To avoid confusion with numbering, these are not included in the Table of Contents or Lists of Figures or Tables.

List of Figures

List of Tables

Glossary

AAEE	Australasian Association for Engineering Education
ABET	Accreditation Board for Engineering and Technology (USA)
ACED	Australian Council of Engineering Deans
ACFID	Australian Council for International Development
ACT	Australian Capital Territory
ANU	Australian National University
AQF	Australian Qualifications Framework
CECS	College of Engineering and Computer Science, ANU
DFAT	Department of Foreign Affairs and Trade
EA	Engineers Australia, formally Institution of Engineers, Australia
EWB	Engineers Without Borders. If used without a country, this refers to EWB Australia.
EWB-A	Engineers Without Borders Australia
EWB-NZ	Engineers Without Borders New Zealand
EWB-UK	Engineers Without Borders United Kingdom
EWB-USA	Engineers Without Borders United States of America
HCD	Human-Centred Design
HumEng	Humanitarian Engineering
HumEngEdu	Humanitarian Engineering Education
LTS	Learning Through Service
MDGs	Millennium Development Goals
NAE	National Academy of Engineering (USA)
NGO	Non-government organisation
NZ	New Zealand
PBL	Project-Based Learning
PBSL	Project-Based Service-Learning
RAE	Royal Academy of Engineering (UK)
RSEng	Research School of Engineering, CECS, ANU
SDGs	Sustainable Development Goals
SL	Service-learning
STEM	Science, Technology, Engineering and Mathematics
UA	Universities Australia
UCD	User-Centred Design
WASH	Water, Sanitation, and Hygiene

Publications

Below are the publications within this thesis ordered by publication date. First authored publications are chapters while articles for which the researcher was a contributing author are appendices.

First Authored (Chapters)

Smith, J., Turner, J., and Brown, N. (2015) Design for Dissemination - Development of a Humanitarian Engineering Course for Curriculum Sharing, *26th Annual Conference of the Australian Association for Engineering Education (AAEE2015) Order of Proceedings*, Geelong, December.

Smith, J., Turner, J., Brown, N. and Price, J. (2016) Integration of a short-term international humanitarian engineering experience into engineering undergraduate studies, *ASEE 123rd Annual Conference and Exposition*, New Orleans, LA, June 26-29.

Smith, J., Compston, P., Male, S., Baillie, C., and Turner, J. (2016) Intensive Mode Teaching of a Humanitarian Engineering Course to Enhance Service-Learning, *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, 11(2), 38–54.

Smith, J., Anderson, B., Brown, N., Colley, A., Stoakley, A., and Turner, J. (2017) The Rise of Humanitarian Engineering Education in Australasia, *28th Annual Conference of the Australasian Association for Engineering Education (AAEE2017) Order of Proceedings*, Manly, December.

Smith, J., Mazzurco, A., and Compston, P. (2018) Student engagement with a humanitarian engineering pathway, *Australasian Journal of Engineering Education*, 23(1), 40–50.

Smith, J., Turner, J., and Compston, P. (2019) Impacts of a humanitarian engineering education pathway on student learning and graduate outcomes. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, 14(1), 1-20.

Smith, J., Tran, A., and Compston, P. (2019). Review of Humanitarian Action and Development Engineering Education Programs, *European Journal of Engineering Education,* Accepted 18/05/2019, https://doi.org/10.1080/03043797.2019.1623179.

Smith, J., Browne, C., and Compston, P. (2019) Integrating Professional and Discipline Practice to Enhance Student Motivation and Employability, *IEEE Transactions on Education*.

Contributing Author (Appendices)

Turner, J., Brown, N., and Smith, J. (2015) Humanitarian Engineering – What does it all mean? *26th Annual Conference of the Australian Association for Engineering Education (AAEE2015) Order of Proceedings*, Geelong, December.

Watts, R., Thomson, A., Smith, J., and Saly, K. (2015) The Design and Installation of Solar Home Systems in rural Cambodia, *2015 Asia-Pacific Solar Research Conference*, December, Brisbane, Australia.

Watts, R., Smith, J., and Thomson, A. (2016) The Design and Installation of Solar Home Systems in Rural Cambodia, *Journal of Humanitarian Engineering*, 4 (2), 16-23.

Creaser, E., Smith, J., Thomson, A. (2018) Perspectives of Solid Waste Management in Rural Cambodia, *Journal of Humanitarian Engineering*, 6 (2), 18-25.

Brown, N., Baynard-Smith, P., Smith, J., Thomson, A., and Browne, C. (2018) An NGO-university partnership for sustainable engineering research solutions, *Partnering for Impact on Sustainable Development*, Development Bulletin 79, January, ANU.

Statement of Contribution

Chapter 2:

Title: Review of Humanitarian Action and Development Engineering Education Programs.

Authors: Jeremy Smith, Anh Tran[a], Paul Compston[b].

[a]Coventry University, UK.

[b]The Australian National University.

Publication: European Journal of Engineering Education.

Current Status: In press.

Author Contributions:

The article sought to identify and review the most similar programs with some level of inclusion of, or emphasis on, humanitarian engineering. This was challenging due to the different terms, definitions and understandings used. To overcome this, I reviewed numerous publications in the broad area to draw out different terms and their associated understandings. This required an understanding of the dialogue in the area, embedded in engineering education, as well as contemporary discussions in established humanitarian action and development fields. It is from these areas that engineering has borrowed terms, although often attaching its own meaning to them. The lack of agreed definitions and understandings at both a national and international level is posing a significant challenge and risk to the sustained viability of the field, its interaction with professional engineering practice and associations and other disciplines, and ultimately the quality of work completed.

I led the overall development of the paper, including the selection of journal, study design, data analysis and writing. I completed all of the data collection and analysis. Additional programs to review were suggested by Anh Tran, while both co-authors reviewed the outcomes from the data analysis. Dr Tran was involved in initial writing providing suggestions and comments, and in some cases specific text, to the *Introduction and Background*, *Results*, *Discussion*, and *Recommendations and Conclusions* sections. Dr Tran contributed directly to the development of Table 1 and completed Table 3 from the data gathered. Dr Tran was involved with consideration of reviewer comments and making suggestions for changes and updates during the revision process. The journal chosen was selected due to its international nature, and the aim of providing a global summary of similar programs. Collaborating with Dr Tran, as a Europe-based researcher, contributed to the selection. While this article was one of the first started during the research, it went through a lengthy review process meaning it was one of the last to be published.

Chapter 3:

Title: Design for Dissemination - Development of a Humanitarian Engineering Course for Curriculum Sharing.

Authors: Jeremy Smith, Nick Brown[a], Jennifer Turner[a].

[a]Engineers Without Borders Australia.

Publication: Proceedings, AAEE2015 Conference, Geelong, Australia.

Current Status: In press.

Author Contributions:

I led the overall development, writing and editing of the publication. It captured the development of the new *Engineering for a Humanitarian Context* elective I convened at the ANU. The paper outlines the specific curriculum development approach used, and how this contributed to the course being able to be delivered to two cohorts of students, one based in Canberra, the other undertaking the EWB Humanitarian Design Summit international short-term study-abroad experience.

I was responsible for selecting the curriculum development approach, which is an adaptation of a common systems engineering design approach which builds from my discipline background. This required a deep understanding of curriculum development and the selected approach, and how it should be applied in practice. I was responsible for leading the curriculum development, which also involved the other authors, and I was required to step them through the various stages of the design approach.

I led the writing, developing the overall structure and extended abstract. I led the writing of most of the sections, with Nick Brown leading the *Summit Delivery* section. I collected the data and quotes presented in the *Discussion* section through course evaluation surveys during the first delivery of the course. All authors reviewed the draft paper and made suggestions and edits, which I then brought together for the final paper. I was the sole presenter of the paper at the AAEE 2015 conference, with myself and Nick present to answer questions. The publication was presented in a stream focusing on *Issues and Challenges in Engineering Education*. This was to emphasise the content of the course rather than the development approach.

Chapter 4:

Title: Integration of a short-term international humanitarian engineering experience into engineering undergraduate studies.

Authors: Jeremy Smith, Jennifer Turner[a], Nick Brown[a], Joli Price[a].

[a]Engineers Without Borders Australia.

Publication: ASEE's 123rd Annual Conference & Exposition, New Orleans, LA, June 26-29, 2016.

Current Status: In press.

Author Contributions:

I took the overall lead on the paper including its development, data collection and analysis, and writing. I identified the conference and links between its themes and this work. My contributions for writing included developing the overall structure, the bulk of the writing, and collating comments from the other authors to complete the finished article. Co-authors made writing contributions in the *EWB Australia Programs* section, as they were involved with the programs described. All authors reviewed the draft paper and provided suggestions, comments and revisions.

The paper describes how the EWB Summit was incorporated into students' study programs at the ANU, outlining three options in Table 1, which I identified and coordinated. I was solely responsible for the primary data collection, captured in Table 2, and quotes in the *EWB Summit Course Integration* section. The overall summary of approaches presented in Table 3 were based on my experiences at the ANU and the data collected, although the approaches were discussed with the co-authors, drawing on their experiences leading the EWB Summit and EWB Undergraduate Research Programs. I synthesised the major outcomes, recommendations and further work, supported by discussions with the co-authors.

The paper was presented solely by myself at the American Society of Engineering Education annual conference in 2016. The paper in the *Diversity in Community Engagement Implementation II* session within the Community Engagement Division.

Chapter 5:

Title: Intensive Mode Teaching of a Humanitarian Engineering Course to Enhance Service-Learning.

Authors: Jeremy Smith, Paul Compston[a], Sally Male[b], Caroline Ballie[b], Jennifer Turner[c].

[a]The Australian National University.

[b]The University of Western Australia.

[c]Engineers Without Borders Australia.

Publication: International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship.

Current Status: In press.

Author Contributions:

This was a collaborative paper focused on the first delivery of the *Engineering for a Humanitarian Context* course at the ANU. The design and development of the course was completed as part of a collaboration project with EWB-A. The course was incorporated into a larger project based at the University of Western Australia (UWA) focusing on intensive mode teaching.

I selected the journal for publication, based on the journal contributors and editors who have significant experience with service-learning and Humanitarian Engineering education. Sally Male and myself were responsible for the overall research within the paper. Dr Male was responsible for the threshold concepts and capabilities data collection and analysis. This included conducting interviews with the teaching team, consisting of myself and Jennifer Turner, the in-class student workshop, and the post-completion focus group and student surveys (data collection elements B, C, G and H in the *Methods* section). This led to the threshold identified and the factors which influenced development of the capability, presented in Tables 4 and 5 and Figures 1 and 2. I was responsible for the other data collection and analysis, specifically entry and exit surveys, in-class discussion, and course evaluations (elements A and D-F). These directly contributed to results in Tables 1 and 6 to 8. Tables 2 and 3 were jointly developed by combining data from multiple collection tools. I was primarily responsible for the overall synthesis of data as I was the only person involved with all aspects of the design, development, delivery and evaluation of the course. This is captured in the *Discussion* section, for which I was the lead author.

I led the overall writing process including final editing. I was directly responsible for writing the *Introduction*, *Context and Background* (apart from the *Intensive Mode Teaching* subsection), *Course Development* and *Conclusions, Recommendations and Continuing Work* sections. The *Methods*, *Results* and *Discussion* sections were written by myself and Dr Male, with Dr Male taking the lead on sections related to the threshold concept and capability elements, and myself on the other data collection. The other authors all reviewed the overall paper and provided suggestions and comments. I was primarily responsible for the revisions made from reviewers' comments, seeking advice from the other authors as required.

Chapter 6:

Title: Student Engagement with a Humanitarian Engineering Education Pathway.

Authors: Jeremy Smith, Andrea Mazzauro[a], Paul Compston[b].

[a]Swinburne University of Technology.

[b]The Australian National University.

Publication: Australasian Journal of Engineering Education.

Current Status: In press.

Author Contributions:

I led the overall development and writing of the paper, including the selection and use of data collection methods and analysis. I selected the journal for publication, chosen for its relevance to the Australasian context of engineering education, and to support dissemination of the outcomes to the primary target audience for the research; engineering educators in Australia and NZ.

The data collection was over a period of 18 months from Humanitarian Engineering education experiences at the ANU. This included student engagement in terms of course enrolment and project selection (presented in Tables 5 to 8), and characteristics captured in surveys (in Tables 9 to 15). Surveys were both baseline surveys for the overall 3rd/4th year engineering cohort and from dedicated Humanitarian Engineering experiences, allowing a comparison to be made. I developed the study design, which in this publication focused on the quantitative elements of the overall mixed-methods approach taken for the study as a whole. I made all decisions on data collection, survey instruments and items, and analysis methods.

Co-authors were involved with data analysis and presentation. In particular they provided peer-review of the analysis made and conclusions drawn, and suggestions for the presentation and structure of sections *3.2. Study design* and *4. Results*. I authored the complete paper, with co-authors reviewing drafts and providing suggestions and comments.

Chapter 7:

Title: Impacts of a humanitarian engineering education pathway on student learning and graduate outcomes.

Authors: Jeremy Smith, Jennifer Turner[a], Paul Compston[b].

[a]Swinburne University of Technology.

[b]The Australian National University.

Publication: International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship.

Current Status: In press.

Author Contributions:

The paper presented quantitative and qualitative results for the outcomes students identified from their engagement with Humanitarian Engineering. The study design described in the *Methodology* selection is a summary of the overall research approach which I designed for the research as a whole. I selected the journal, which was chosen due to the specialist focus of the research. This journal provided the greatest opportunity for review by experienced researchers in the area, and to contribute to the international body of knowledge in the field.

I completed all the data collection outlined, including surveys and interviews with the 21 graduates. Co-authors were involved with aspects of the data analysis, in particular reviews of interview transcripts and identification of emergent codes and overarching themes. I authored the entire paper. Co-authors reviewed the completed paper and provided comments and suggestions, particularly Jennifer Turner on data presentation and overall discussion and conclusions. I was solely responsible for changes based on reviewers' comments and for the final copyedits.

Chapter 8:

Title: Integrating Professional and Discipline Practice to Enhance Student Motivation and Employability.

Authors: Jeremy Smith, Chris Browne[a], Paul Compston[a].

[a]The Australian National University.

Publication: IEEE (Institute of Electrical and Electronics Engineering) Transactions on Education.

Current Status: Rejected[2].

Author Contributions:

This journal article utilises the data and analysis completed in the study to develop a high-level design for an engineering undergraduate degree program that utilises multiple domain-specific application pathways. This idea emerged from my analysis in this research, based on findings that students gained additional motivations and positive outcomes by having the opportunity to apply their engineering skills and knowledge in an area of interest to them. The Humanitarian Engineering pathway was an example of this. The initial concept was developed further by myself and the second author Chris Browne. Dr Browne then extended the concept through individual course descriptions and curriculum design, which was required for the academic approval process which he led. This detail is not captured in this article, rather this focuses on the high-level conceptual program design based on my research in this study.

[2] Note: after external examination of this thesis, the article was rejected but is including for completeness of the as examined thesis.

I championed the ANU's involvement in the National Academy of Engineering (NAE) Grand Challenge Scholar Program which is discussed in the article. This involved identifying the program, seeking approval from our executive leadership team to be involved, developing the structure of the program at the ANU, completing the relevant documentation, and leading its implementation and operation as Program Director, supported by a committee.

I led the writing of the article including the selection of journal, the focus and abstract, and the development of the structure. I completed the writing of the entire first draft, which was then reviewed by the contributing authors who provided comments and suggestions. I then edited the article to complete the version as submitted. The journal was selected to provide a broader engineering education audience as the concept developed was beyond solely Humanitarian Engineering.

Chapter 9:

Title: The Rise of Humanitarian Engineering Education in Australasia.

Authors: Jeremy Smith, Bianca Anderson[a], Nick Brown[a], Alanta Colley[a], Alison Stoakley[a], and Jennifer Turner[b].

[a]Engineers Without Borders Australia.

[b]Swinburne University of Technology.

Publication: Proceedings, AAEE2017 Conference, Manly, Sydney, Australia.

Current Status: In press.

Author Contributions:

In this collaborative paper, I led the overall writing and editing process. This included developing the structure, writing the extended abstract, and identifying the data requirements. I completed the majority of the writing, with paragraphs on individual EWB programs in the *Humanitarian engineering education in Australia and New Zealand* section written by the program leads at EWB-A. Co-authors from EWB-A provided the data for Figure 1 while formatting of the Figure was completed by Jennifer Turner. I was responsible for the collection of data presented in Table 1 on the status of Humanitarian Engineering education initiatives at universities in Australia and New Zealand. This utilised my connections and networks, and built from discussions I held with many of the program leads and academic champions at the various institutions. The *Impacts of humanitarian engineering education* section was written collaboratively. I took the lead for the *Opportunities and recommendations for the future* section, which required the synthesis of the data presented in the paper in addition to observations and lessons from literature on programs international, as well as an understanding of the broad engineering education landscape of Australia. As the only academic involved at the time of writing, I engaged the most with the literature and existing work from other countries.

I was the sole presenter of the paper at the AAEE Conference, where this was the first paper across two dedicated sessions focusing on *Integrating Humanitarianism in Engineering Education*, for which I was a co-proposer and co-convenor.

Chapter 1: Introduction to Study

This thesis is a compilation of publications completed during the researcher's candidature. Each publication is standalone, presented as individual chapters. To offer a narrative and bind the work, this introduction is provided along with a foreword to each chapter and a conclusion. This Chapter outlines the field of study and its context, the local setting where the investigation was conducted, research questions, study aims and scope. The overarching research design and methodology is described along with alternatives that were considered and not used. Personal motivations and the role of the researcher are provided to locate the author within the study and potential influences. The structure of the rest of the thesis is presented, highlighting how the publications in the proceeding chapters address the research questions, complement each other, and relate to the overall research.

1.1 Field of Study

The research here addresses *humanitarian engineering education*. This integrates contemporary engineering practice, engineering education, and the humanitarian action and development sectors, as shown in Figure 1.1. These topics will be introduced in turn before being drawn together, first through humanitarian engineering and then humanitarian engineering education itself.

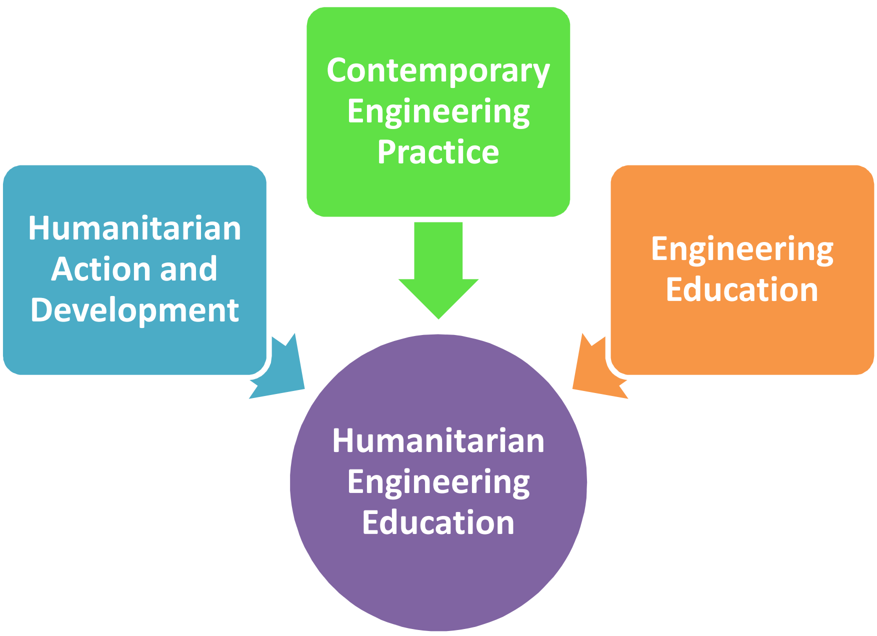


Figure 1.1: Fields of study leading to the focus of the research on humanitarian engineering education.

1.1.1 Humanitarian Action and Development

Since the industrial revolution in the mid-18th century, engineering has been creating progressively greater impacts on day-to-day life in societies and communities globally (UNECSO 2010). However, many countries, communities and individuals still face significant levels of disadvantage, poverty, and vulnerability. This can be in the form of high levels of vulnerability to natural disasters and their impacts, increased levels of poverty and health risks, or lack of natural resources, education, economic opportunity or social participation. Traditionally *humanitarian action*, which is also referred to as humanitarian response, aid or intervention, or disaster response, addresses short-term actions to natural disasters such as earthquakes, floods, serve storms or hurricanes (UNHCR 2018). Work to overcome poverty, improve long-term health, and provide access to basic infrastructure, services, and economic development, is called *development* (Tayler 2016, OECD 2017). There is overlap between short-term humanitarian action and long-term development, and so these are often represented as a spectrum moving from short- to long-term as shown in Figure 1.2 (Greet 2014).

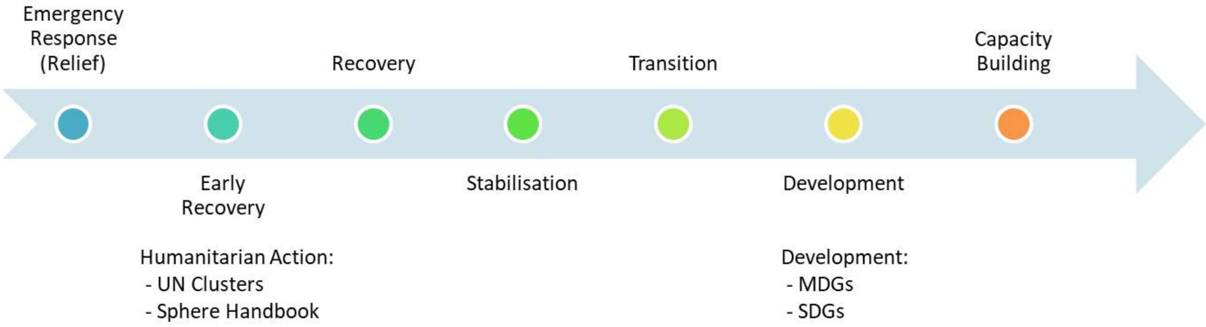


Figure 1.2: The humanitarian action - development spectrum, including key organisations and frameworks (adapted from Greet 2014).

The long-term development challenges facing the modern world and its population are beyond the scope and influence of a single discipline such as engineering. Globally, 2.3 billion people do not have access to basic sanitation facilities, and almost 900 million practice open defecation (WHO 2017a). Highlighting the interrelated nature of these challenges, two billion people drink from a water source contaminated with faeces, human or animal, while over 800 million people lack access to a source of potable (clean) drinking water (WHO 2017b). In terms of energy, 1.2 billion people lack access to electricity and 2.7 billion do not have access to clean cooking facilities (IEA 2018).

Many of the world's contemporary development challenges are encapsulated in the Sustainable Development Goals (SDGs). The SDGs are a global framework of 17 goals, 169 targets and 232 indicators across areas including health, education and gender, that seek to eradicate poverty by 2030. They were finalised in 2015 and have been adopted by 193 countries. The SDGs superseded the Millennium Development Goals (MDGs) which operated from 2000 to 2015 with the aim of halving poverty over that period. The eight MDG targets were more focused than the SDGs, and measured progress against extreme poverty, primary education, child mortality and maternal health. (UN 2016)

Despite progress against the MDGs, the scale and nature of the challenges within the SDGs is vast. While *engineering* is only explicitly mentioned once in the goals, targets and indicators (and then in relation to scholarships), the role of engineering is clear with *technology* and *infrastructure* being mentioned in 9 of the 17 SDGs. For example, Goal 7 is *Ensure access to affordable, reliable, sustainable and modern energy for all,* Goal 9 is *build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation*, while Goal 17, *strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development* includes *technology* as one of five sub-themes (UN 2016). Here, engineering and technology are enablers to support larger positive social change, not an ends in-themselves. For example, target 5.b (in Goal 5) is *Enhance the use of enabling technology, in particular information and communications technology, to promote the empowerment of women* (UN 2016).

Beyond the SDGs, with their focus on long-term human development, engineering has a role in short-term disaster response and management. In 2017, natural disasters caused 9,967 fatalities, affected 96 million people, and caused US$334 billion of economic damage (CRED 2018). While the fatalities and people affected were below the 10-year averages, 68,274 and 210 million people respectively, economic loss was more than double the average of US$142 billion (CRED 2018). The role of engineering in such situations can range from the immediate first response to a natural disaster through to planning and preparation for future potential events. Engineering can support responses to disasters to reduce loss of life, establish temporary (although sometimes long-term) camps for survivors, and assess damaged infrastructure and environments to assist with rebuilding.

To enhance short-term humanitarian action, the UN has adopted a *Cluster Approach* for the coordination of non-refugee humanitarian emergencies involving conflict or disasters. Clusters are groupings of related organisations and agencies. Eleven clusters for the main sectors of humanitarian responses have been developed including education, early recovery and protection. As with the SDGs, engineering and technology is present in many of the clusters, including emergency telecommunications, logistics, shelter, and water, sanitation and hygiene (WASH) (UNHCR 2018).

To support on the ground disaster response, the *Sphere Project* is a voluntary initiative for humanitarian organisations and agencies established in 1997. One of its key resources is the Sphere Handbook, officially the *Humanitarian Charter and Minimum Standards in Humanitarian Response*. This provides "recognized sets of common principles and universal minimum standards in life-saving areas of humanitarian response". It includes technical chapters in four areas: WASH; food security and nutrition; shelter, settlement and non-food items; and health action. Links to the UN Clusters can be seen as well as the engineering and technology which supports and enables these areas. (Sphere n.d.)

Across the SDGs, UN Clusters and Sphere Project, humanitarian action and development seeks to actively overcome disadvantage, marginalisation or vulnerability and the impacts and consequences they bring across the humanitarian and development spectrum. Disadvantage can take the form of lack of access to basic human needs such as food, water, shelter and healthcare. Vulnerability is to the impacts of natural disasters and other external shocks over which individuals have no or limited control. Marginalisation can occur where the benefits and impacts of technology are not available to a particular section of society. Reasons for this lack of availability can vary from local economic, social and environmental factors such as natural resources, education levels and poverty, through to deliberate exclusion through policy and discrimination. (UNECSO 2010)

As for any country, Australia has measureable levels of disadvantage, marginalisation and vulnerability. Contemporary domestic challenges in Australia include impacts of climate change and access to secure and reliable energy, telecommunications and water. Across disadvantage, vulnerability and marginalisation, engineering and technology have roles to play within appropriate public policy. For example, specific risks for Aboriginal Australians and people with disabilities are present, with these groups on average having lower income, health and education indicators than the overall population (ACOSS 2014). The *Closing the Gap* government strategy, committed to in 2007 by all levels of Australian government, seeks to address gaps across seven areas in health, education, income and life expectancy between Aboriginal and non-Aboriginal Australians. Demonstrating the complexity of this work, in 2017, the ninth annual progress report highlighted that five of the seven goals were not on track to be met (CoA 2017). The National Disabilities Insurance Scheme (NDIS), established in 2013 with a focus on people with disabilities, is providing opportunities to make individual purchasing decisions based on aspirations and needs. This is expected to drive the creation of new markets and opportunities for assistive technology development, with an estimated $22 billion annual investment once fully operational in 2019/2020 (NDIS n.d.).

1.1.2 Contemporary Engineering Practice

Contemporary engineering as a dedicated profession emerged in the early 19th century with the creation of "civil" associations, to differentiate civilian engineering from established military focused engineering. Since then, the practice of engineering has come to be governed through professional associations. In Australia, this is Engineers Australia (EA), which was established in 1919 (EA 2017a). Such organisations are typically responsible for the setting of standards for various levels of professional practice, from graduates through to experienced practitioners. Such standards are often captured in competency frameworks which specifically articulate the competencies or skills of an engineer at different stages of their careers, such as EA (2011) for graduate competencies. In the USA, ABET is responsible for the accreditation of post-secondary education programs, which enables graduates from accredited programs to be recognised as engineers (Litchefield et al 2016). Mobility agreements between countries, such as the Washington Accord, provide equivalence of competency and allow engineers to operate in different locations (Dowling and Hadgraft 2012).

As it has done since it emerged as an area of professional practice, engineering is going through change. This is partly driven by the outcomes of the profession itself, in the form of rapid technology development, a world connected by physical and virtual infrastructure, and global transport, logistics and supply chains. These have driven engineering in the 21st century to be global, where local decisions and technology have impacts beyond physical and virtual boundaries (UNESCO 2010). Demonstrated most clearly by climate change, all societies are now facing the impacts of global challenges with a reach, scale and complexity not previously experienced. Emphasising the nature of contemporary engineering, numerous studies have identified competencies, knowledge and mindsets for *global engineers* (Bourn and Neal 2008, Jesiek et al 2014, Lohmann et al 2006). Although these highlight a variety of definitions and understandings of global engineering, an international focus is embedded within all engineering to some extent.

Professional associations and learned societies around the world have explored the role of engineers in the 21st century. In 2010, UNESCO produced its first, and so far only, report on engineering; *Engineering: Issues, Challenges and Opportunities for Development* (UNESCO 2010). This explicitly linked engineering to human action and development at international and regional levels. It articulated the role of engineering for development in areas including poverty reduction, climate change, sustainable development, emergencies and disasters, and appropriate technology for community development.

At a national level, reports from the Royal Academy of Engineering (RAE) in the UK and the US National Academy of Engineering (NAE) have described the roles of engineers in working on the global challenges of the 21st century, including contemporary and emerging humanitarian and development opportunities and challenges. In 2008, before the SDGs commenced, the NAE identified its *14 Grand Challenges for Engineering in the 21st century*, grouped into four themes; *sustainability*, *health*, *security* and *joy of living* (NAE 2008). These are engineering-focused; for example, they do not directly mention or address challenges related to inclusion, equality or empowerment. However, some of the challenges that can be directly mapped to goals and targets within the SDGs including (NAE 2008, UN 2016):

- Engineer better medicines - Goal 3: Good health and well-being for all.
- Provide access to clean drinking water - Goal 6: Clean water and sanitation.
- Make solar energy economical - Goal 7: Affordable and clean energy.
- Restore and improve urban infrastructure - Goal 11: Sustainable cities and communities.

Similarly, the UK RAE produced a number of reports which placed "engineering at the heart of society, underpinning and continually improving the quality of our lives" (RAE 2015). In Australia, EA in its 2017/18 - 2019/20 strategic plan added the statement "Engineers Australia shapes the future of Australia - creating happy, healthy, prosperous and sustainable communities" (EA 2017a). These areas overlap almost exactly with the NAE's four themes of their 14 grand challenges.

A recent definition of engineering by the Australian Council of Engineering Deans (ACED) (EA 2017b), while not mentioning community, did specifically identify human needs and contextual factors:

"*Engineering draws on scientific, mathematical and technological knowledge and methods to design and implement physical and information-based infrastructure, products, systems and services that address human needs, safely and reliably. Engineering takes into account economic, social, environmental, and aesthetic factors.*"

Since 2015, ACED have produced position papers on the following topics related to engineering practice in Australia (ACED 2019):

- Promoting engagement between industry and universities for improving engineering graduate capabilities and accelerating innovation, December 2016.
- Increasing the Participation of Women in Engineering Education, March 2017.
- Indigenous (Aboriginal) Engineering, Australian engagement and engineering and humanitarian engineering, August 2017.
- Humanitarian Engineering, April 2018 (see Appendix VIII).
- Mathematics requirements for engineering education, February 2019

These reports and research from numerous organisations link contemporary engineering practice directly to human development and quality of life. This shifts the emphasis of engineering from purely technology development and the application of maths and science to contributing to human well-being and sustainable development.

In parallel to the development of engineering practice over the last two centuries has been changes in perspectives of engineering ethics and loyalty. The development of profession ethics in engineering (in the US at least) was explored in Mitcham (2009). This identified a number of phases for the development of engineering codes of ethics. The two main phases of the 20th century were *ethics as loyalty* and *ethics of efficiency*. Both of these emphasised service and loyalty to the engineers' employer and client, seeking to deliver the most efficient technical solutions to the client. It was in the second half of the 20th century that ethics linked to *public safety, health and welfare* started to emerge. Here engineers have a higher ethical responsibility to society as a whole, often through their professional associations, which supersedes loyalty to an employer or client. This approach has now been captured through recent codes of ethics, such as that of EA (as seen in Table 1.1 below), in particular a focus on social responsibility and sustainable development. (Mitcham 2009).

The inclusion of social responsibility in engineering was explored in Litchfield and Javernick-Will (2015;2016). Through a large study of students and engineers involved and not involved with Engineers Without Borders USA, a "socially engaged engineering" organisation, they found members often described themselves "an engineer AND". The addition incorporated a range of broader interests not traditionally viewed as part of engineering including a focus on working with people and striving for positive social impact. This could in-part capture the split loyalty, or even split-personality, of engineering, where engineering activities and outcomes are seen as separate to social engagement despite the social context of engineering at its impacts. (Litchfield and Javernick-Will 2015).

1.1.3 Engineering Education

To support changes in engineering practice and demands, many competency frameworks that govern engineering education have shifted to an *outcome* focus defining the expectations of an engineer to practice rather than the knowledge and skills required (Conlon 2008).

Table 1.1: Selected EA graduate competencies and conduct for the broader application of engineering (EA 2011, EA 2013).

Elements	From
1.5. Knowledge of contextual factors impacting the engineering discipline.	Stage 1 Competency Standard
1.6. Understanding of the scope, principles, norms, accountabilities and bounds of contemporary engineering practice in the specific discipline.	Stage 1 Competency Standard
2,3. Application of systematic engineering synthesis and design processes.	Stage 1 Competency Standard
3.1. Ethical conduct and professional accountability.	Stage 1 Competency Standard
3.2. Effective oral and written communication in professional and lay domains.	Stage 1 Competency Standard
1.3 Respect the dignity of all persons.	Code of Ethics
3.2 Support and encourage diversity.	Code of Ethics
4.1 Engage responsibly with the community and other stakeholders.	Code of Ethics
4.2 Practise engineering to foster the health, safety and wellbeing of the community and the environment.	Code of Ethics
4.3 Balance the needs of the present with the needs of future generations.	Code of Ethics

In many developed countries, including Australia, graduate engineering competencies revised since 2000 now make specific mention of broader engineering practice, moving beyond the traditional application of fundamentals such as maths, science and specific engineering discipline knowledge. Competencies for the application of engineering knowledge and the processes to do so are articulated as well as professional requirements for teamwork and communication. Engaging with society at large is stated, in particular within the context of sustainability to address the triple-bottom line of economic, environmental and social factors. Examples of these competencies from Engineers Australia's (EA) Stage 1 Competencies for a Graduate Engineer along with elements of EA's Professional Code of Conduct, which was released in 2013, are shown in Table 1.1.

Undergraduate engineering education in Australia is primarily governed by the Stage 1 competency framework established by EA. Programs are accredited by EA through an independent panel every five years. This provides recognition through international mobility frameworks such as the Washington Accord. Degrees must meet the descriptors of the Australian Qualifications Framework (AQF). Four-year undergraduate degrees in Australia typically include an honours component meaning they sit at AQF Level 8. The Australasian Association for Engineering Education (AAEE) provides an annual conference, journal and professional development opportunities, to grow the capacity of engineering education and encourage scholarship in the area. ACED meets on a regular basis to discuss the state of engineering education, challenges, and identify collaborations and common goals. Additional drivers in engineering education in Australia at the time of the study include increasing diversity within engineering degree programs (ACED 2017, EA 2017c), enhancing the overall student experience, preparing graduates for the contemporary workforce, and enhancing employability skills (ACED 2016).

1.1.4 Humanitarian Engineering

Embedded in the revised competencies of graduate engineers, the global nature of engineering, and the focus on the impacts of engineering, is recognition that engineering can have a profound and lasting impact on quality of life. Engineering can be used to address disadvantage, marginalisation and vulnerability for both short-term humanitarian action and long-term development as captured in the SDGs, UN Clusters and Sphere Project. This was explicit in the UNESCO (2010) report, which identified the role of engineers in development and humanitarian action.

Such engineering, which seeks to apply engineering practice across the humanitarian action and development spectrum, is referred to using multiple terms including *development engineering*, *engineering for sustainable development*, *engineering in emergencies*, *engineering for developing communities*, *engineering for social justice* and *humanitarian engineering*. The exact nature and focus varies from term to term, although a common element is an active and conscious action to harness engineering knowledge, skills and competencies to improve measurable indicators of quality of life. Within this research, *Humanitarian Engineering* (HumEng) will be used collectively to cover the breath of terms for the purposes of this study only. Individual chapters and publications will address the differences in understandings and their implications where relevant. The education of engineers able to effectively operate as humanitarian engineers is referred to as Humanitarian Engineering Education (HumEngEdu).

HumEng emerged in the early 1980's at a time when international attention to significant humanitarian challenges and the collaborations necessary to address them was heightened (Paye 2010). Individuals in international non-government organisations (NGOs) started to examine the design and development of engineering and technology within their programs and interventions (Cuny 1983). During the 1980's, specialist organisations such as Ingenieurs sans Frontieres (ISF, Engineers Without Borders) in France and RedR (Register of Engineers for Disaster Relief) in the UK were established. The mid- to -late 1990's saw increased attention to humanitarian engineering, with further organisations established including other country-based Engineers Without Borders (EWBs) in Europe, and Engineers Against Poverty in the UK. Dedicated HumEngEdu started to emerge in the US with courses and opportunities under various terms being delivered. From the early 2000's there was a rapid expansion in both organisations and education opportunities including numerous national EWBs outside Europe, potentially coinciding with a renewed focus on development and poverty through the MDGs. However, outside these dedicated organisations, terms such as humanitarian or development engineering were uncommon and not widely used or known.

Humanitarian engineering in Australia has a relatively short history. The term *Humanitarian Engineering* was only in limited use in Australia until 2011, which was declared by EA as the *Year of Humanitarian Engineering*. The two most prominent organisations are RedR Australia and EWB-A, established in 1992 (RedR 2017) and 2003 (EWB 2017) respectively. EWB-A describes itself as a humanitarian engineering organisation, while RedR is "a leading humanitarian agency for international emergency relief", although the term humanitarian engineering is used by volunteers (RedR 2017). The development and humanitarian context of Australia is different to countries with a longer history with HumEng such as the USA, UK, Spain, Belgium, France and other parts of Europe. Australia's history and position in the world, both geographically and economically, presents its own domestic and regional development and humanitarian challenges, approaches and priorities. Australia's domestic development priorities, embedded in history since European settlement, are unique.

1.1.5 Humanitarian Engineering Education

With the emergence of global engineering, renewed professional competencies, and dedicated HumEng organisations, came the growth of HumEngEdu (Chapter 2 provides a detailed review of programs in the area internationally). These seek to provide skills, knowledge and competencies to enable engineers to contribute to humanitarian and development responses and outcomes. However, there appears to be no agreed set of outcomes or competencies for education programs.

When compared to North America and Europe, HumEngEdu in Australia is more recent with both EWB-A and RedR offering education opportunities. RedR has an established training program focused on professional development for field practitioners covering a range of disciplines and topics in humanitarian aid and assistance beyond only HumEng. These are becoming available to university students through agreements between individual institutions and RedR. While isolated opportunities, projects and courses were provided by Australian universities, the first widespread initiative to bring attention to the role of engineers in development was the *EWB Challenge*. Launched nation-wide by EWB-A in 2007, the EWB Challenge was rapidly adopted by universities in Australia and New Zealand to support curriculum renewal of first-year programs and the broader competencies set by EA (Cutler et al 2011, Jolly 2014). Since the emergence of the EWB Challenge, EWB-A has been central to the expansion and visibility of HumEngEdu in Australia.

EWB-A education initiatives are targeted at university degree programs and as of 2017 include:

- *EWB Challenge*: a design-focused program for first year engineering students. In collaboration with a community partner, a range of project topics and thematic areas are identified. Partners, and hence context, change each year although similar topics are scoped. It is for individual universities to determine how the EWB Challenge is used and incorporated into courses, but it is typically included in first year introductory engineering courses to provide an overview of the breadth of engineering skills, competencies and knowledge.
- *EWB Humanitarian Design Summits (EWB Summits for short)*: two-week international study tours. They include in-country workshops exploring development, HumEng, cross-cultural awareness, strength-based development approaches, user-centred design, and local languages. A community home-stay of 4-5 days is provided to give an opportunity for participants to practice the tools and methods taught, and integrate their discipline engineering knowledge. Summits are offered during the Australian summer and winter, to countries in the Asia-Pacific including Nepal, Cambodia, India, Samoa, Timor-Leste and Malaysian Borneo.
- *EWB Undergraduate Research Program*: provides projects scoped by EWB and its partners for individuals and groups of students to incorporate into final year research

and development projects. These are service-learning projects in that students learn through the process of providing a service to an external community or NGO partner.

HumEngEdu for the Australian engineering, education and development context is only just starting to be explored. The pedagogically approaches and outcomes from research and delivery in countries can provide lessons for Australia. However, due to the unique Australian HumEng context, existing approaches and programs cannot simply be imported and applied directly to Australian engineering education, curriculum must be contextualised as highlighted in the Higher Education Learning Framework principle "contextual learning" (Nugent et al 2019).

HumEngEdu in Australia needs to be investigated to identify the required content, desired outcomes, delivery approaches, overall student experience, and outcomes and benefits that it achieves for Australia's unique national context. Work on single initiatives such as the EWB Challenge (Jolly 2014) and EWB Australia's Undergraduate Research Program (Smith et al 2009, Brown et al 2018) have been conducted as well as evaluations in specific areas such as social justice (O'Shea and Baillie 2011). Research in HumEngEdu in Australia needs to be completed to establish a profile and understanding of the students who are engaging with it, the student outcomes achieved and the influence of HumEngEdu on professional practice, career choices and motivations.

It is within the context of HumEngEdu for Australia that this research study is positioned. It seeks to support and assist the growth and delivery of HumEngEdu in Australia. The thesis documents and evaluates the development of a first-in-country Australian HumEngEdu pathway at a single university. The pathway is explored in terms of its curriculum design and development, and evaluation of student motivations, engagement and outcomes. The research provides opportunities and alternatives for further curriculum development and support of HumEngEdu in Australia.

1.2 Purpose of Study

The purpose of this study is to development and evaluate humanitarian engineering education in the Australian context. This includes the development of HumEngEdu initiatives, content, and experiences, and evaluation of student engagement and outcomes at a single institution.

1.2.1 Research Questions

This study addresses three research areas:

1. *Curriculum* approaches necessary for HumEngEdu:
   1.1. What curriculum approaches can achieve outcomes for HumEngEdu?
   1.2. What combination of curriculum approaches are required for HumEngEdu programs and pathways?
2. *Student engagement* with HumEngEdu:
   2.1. Which HumEngEdu initiatives and experiences do students engage with and when in their studies?
   2.2. What are the key motivations for students to engage with HumEngEdu?
   2.3. What is the profile of students that engage with HumEngEdu?
   2.4. How does the profile of students engaging with HumEngEdu compare to a broader engineering student cohort?
3. *Outcomes* for students from their engagement with HumEngEdu:
   3.1. What knowledge and competencies for HumEng are students achieving?
   3.2. How do students integrate HumEng with the rest of their studies?
   3.3. What other outcomes are being achieved by students through their engagement with HumEngEdu?

The hypothesis is set that engineering education that includes humanitarian engineering will produce more effective engineers as assessed across the full range of EA Stage 1 competencies. Engaging with HumEngEdu will provide engineering graduates skills and outcomes beneficial and relevant for all engineering practice.

Although the structure of the thesis is discussed in more detail in Section 1.7, Table 1.2 above highlights the specific chapters where individual research questions are addressed.

Table 1.2: Chapters where specific research questions are addressed.

Research Question	Chapters Where Addressed
1. *Curriculum* approaches necessary for HumEngEdu	
1.1 What curriculum approaches can achieve outcomes for HumEngEdu?	2, 3, 4, 5, 6, 8
1.2 What combination of curriculum approaches are required for HumEngEdu programs and pathways?	2, 3, 5, 6, 8, 9
2. *Student engagement* with HumEngEdu:	
2.1. Which HumEngEdu initiatives and experiences do students engage with and when in their studies?	5, 7, 8, 9
2.2. What are the key motivations for students to engage with HumEngEdu?	6, 7, 8
2.3. What is the profile of students that engage with HumEngEdu?	7, 8, 9
2.4. How does the profile of students engaging with HumEngEdu compare to a broader engineering student cohort?	7, 8, 9
3. *Outcomes* for students from their engagement with HumEngEdu:	
3.1. What knowledge and competencies for HumEng are students achieving?	6, 8, 9
3.2. How do students integrate HumEng with the rest of their studies?	5, 8, 9
3.3. What other outcomes are being achieved by students through their engagement with HumEngEdu?	8, 9

1.2.2 Significance of Study

HumEngEdu has been delivered overseas since at least the 1990's but it only started to emerge in Australia in 2007 with the growth of EWB-A and its education programs. Since 2015, HumEngEdu in Australia and NZ has undergone rapid expansion with numerous universities simultaneously developing programs and educational opportunities (see Chapter 9 for details). The research undertaken here captures significant elements of this growth, including the first Australian dedicated later year humanitarian engineering course, the first inclusion of the international EWB Summit within a course, the first cohesive pathway across all years of a degree program, in Australia, and the first humanitarian engineer by education, as opposed to field and professional experience, in Australia.

The design and delivery of curriculum, and evaluation of student learning are the new and novel contributions of this work. It is the first evaluation in Australia of multiple engagements with HumEngEdu developed for the unique Australian context. Documentation and evaluation of these initiatives will provide resources and evidence to share and inform the further growth of HumEngEdu. Where relevant, additional drivers present in Australian engineering education will be investigated to explore the potential of HumEngEdu to make contributions beyond HumEng, and impact on engineering education, and hence professional practice, more broadly.

1.2.3 Aims, Scope and Assumptions

This research presents the design, delivery and evaluation of student engagement with, and outcomes from, a new HumEngEdu pathway within an engineering degree program at an Australian university, the ANU. The project aims to collect evidence and complete research and analysis to support further development of HumEngEdu within the context of the study at the ANU as well as other universities, particularly in Australia but potentially internationally as well. The target audience for the work and its outcomes are engineering educators, hence the selection of the conferences and journals to publish and dissemination outcomes from the study. Contributions will be targeted at HumEngEdu but, if relevant, research outcomes may contribute to engineering education programs in Australia, such as program structures, pathways, student outcomes and curriculum approaches.

The research undertaken in this work was:

1. The first year (2015) addressed the first research question by researching, designing and establishing a pathway, including the *Engineering for a Humanitarian Context* course and mechanisms for incorporating the EWB Summit into coursework.
2. The second year (2016) focused on the second research question. The research supported the first cohort of students through the pathway and established initial data collection and analysis, and finalised further data collection methods.
3. The third year (2017) continued work on the second research question and began investigating the third. This was through data collection and analysis, discussions across organisations on HumEngEdu, and expansion of international experiences.
4. The fourth year (2018) synthesised the research and findings across all three research questions through further analysis and documentation, as well as the dissemination of findings for research and education practice.

The study built upon existing curriculum and opportunities in place at the ANU, summarised in Table 1.3. The design and delivery of these existing initiatives and experiences was outside the scope of the research. Where relevant, these existing initiatives were incorporated into the pathway developed and were used for data collection.

Research in this study was undertaken to build a cohesive HumEng focused pathway across all year levels for engineering students at the ANU. The term *pathway* is used to refer to a cohesive set of courses and initiatives with a specific focus, but not one which leads to a formal university award. The latter are referred to as *programs* in order to differentiate between pathway and program. Included in the scope of this study is the development and delivery of new courses and initiatives as completing curriculum development was required to investigate a number of the research questions.

Table 1.3: Existing initiatives and opportunities for students to engage in HumEng at the ANU before the research commenced.

Initiative	**Students**	**Focus or Content**
ENGN1211 Discovering Engineering	All first year engineering students at the ANU.	Incorporated the EWB Challenge into project-based work for all students.
ENGN2225 Systems Engineering Design	All second year engineering students at the ANU.	Students could select a topic with a HumEng focus from a range of potential areas for project work.
ENGN2226 Systems Engineering Analysis	All second year engineering students at the ANU.	Students could select a topic with a HumEng focus from a range of potential areas for project work.
ENGN3100 Practical Experience	Compulsory work experience requirement for all engineering students at the ANU.	Opportunity to complete work experience with a HumEng focus or organisation.
ENGN4200, ENGN4712 Individual Research Project	All final year engineering students at the ANU.	Opportunity to complete a final year individual research project over two semesters with a HumEng focus.
ENGN4221 Systems Engineering Project	All final year engineering students at the ANU.	Opportunity to complete a group capstone style project over one semester with a HumEng focus.
EWB-A Chapter	Students at the ANU.	Voluntary extra-curricular involvement with the local ACT Chapter of EWB-A.

Academics and convenors for the courses in Table 1.3 could incorporate HumEng or related content if relevant for the requirements of the course and its learning outcomes. Academics and convenors did not modify or alter their course content, curriculum or delivery for the purposes of this work, and hence were not directly involved in the research here. They may have been involved in allowing data collection to take part within courses or identifying projects with a HumEng scope or focus to assist with identifying potential participants. The researcher was not involved in delivering these courses during the research.

Students could enter the new HumEngEdu pathway at various points and have multiple engagements. Extra- and co-curricular experiences contribute to HumEngEdu outcomes and are included within the study. Some HumEngEdu content and topics have been developed, delivered or supported by other staff and students including project and assignment topics in the core courses in Table 1.3 and the supervision of final year research and group projects. Engagement and outcomes from these are within the scope of this research.

The study focuses only on students engaging in the pathway developed in the context of the study. It does not include students from other universities, although students within the study did have the opportunity to engage with other universities through international experiences. The focus is undergraduate students, with masters coursework students included in courses and studies where they have undertaken opportunities available to them, for example through double-badged courses and international experiences. The focus is higher education, aligned with professional accreditation requirements. This excludes professional development and training, such as that offered by RedR Australia, unless it is contributing to an accredited degree program or undertaken as an extra-curricular activity.

Within this study, HumEng is taken to cover the spectrum of humanitarian action and development contexts and settings. While in a traditional sense humanitarian work focuses on disaster relief and response, a broader interpretation will be taken in this study in line with the emerging understanding of the term *Humanitarian Engineering* in Australasia (see Appendix III). This covers all the activities in the spectrum in Figure 1.2, from emergency response, through disaster recovery to development addressing long-term or systemic development challenges such as those within the SDGs. It covers domestic (Australian) and international (overseas) work equally.

To differentiate EWB Australia from other independent EWB organisations, the acronym EWB-A will be used. Where programs offered by EWB-A are mentioned, they use the official program name. For example, *EWB Summits* and the *EWB Challenge* are operated by EWB-A.

1.3 Context of Study

This research study is contextually set within the field of HumEng in Australia, and the spatial context of the institutional and educational setting of the ANU.

1.3.1 Humanitarian Engineering Organisations in Australia

While EWB-A and RedR are the two largest organisations with a focus on HumEng in Australia, there are other organisations that could be considered humanitarian engineering-focused although they may not position themselves as such. For example, domestic organisations like the Centre for Appropriate Technology (CAT) work with rural and remote Aboriginal communities. International NGO's such as Oxfam, Live and Learn Environmental Education, and WaterAID, incorporate engineering and technology development within their work but do not focus solely on engineering expertise. Smaller NGO's, like Abundant Water, focus on technology development but without the reach or breadth of larger organisations.

Within the Federal Department of Foreign Affairs and Trade (DFAT), AustralianAid administers the Australian Government's international aid program. In 2015 InnovationXChange (iXc) was established within DFAT to support new innovation and private sector engagement with aid and development (iXc 2017). DFAT administers the New Colombo Plan (NCP) which provides scholarships to Australian domestic university students to undertake a learning experience in the Indo-Pacific (Asia-Pacific) region. Both EWB-A and RedR have at times received support from AustralianAid and its long-term predecessor AusAID.

International aid and development from Australian organisations typically targets the Asia-Pacific region, in particular South-East Asia and the Western Pacific. ACFID (Australian Council for International Development) provides a platform and network for Australian international development and non-government aid organisations to collaborate, engage with the Federal Government, and strengthen approaches (ACFID 2015). Both EWB-A and RedR are members of ACFID. Domestically, various levels of state and federal government are involved with public policy and support for disadvantaged individuals and communities, along with a range of social enterprises and NGOs.

1.3.2 Institutional Setting

This research takes place at the ANU in Canberra in the Australian Capital Territory (ACT). Canberra was established as the capital of Australia after Federation in 1901, although it did not become the location of parliament until 1927. Canberra is a planned city with a high percentage of government employees, with 42% of the total ACT workforce employed by the Federal or ACT Governments (ABC 2017). The city has continued to grow and the ACT had a population of just over 400,000 as of 2016 (ABS 2017). Canberra has higher average income and education levels than the national average. From the 2016 national census, the ACT had the highest median household weekly income in Australia, approximately 50% higher than the national average, while it also has the highest life expectancy and education levels, with residents having on average twice the educational attainment of the rest of the country (ABS 2017, Cassells et al 2012).

The ANU is a single urban campus on the edge of the city centre. It was established in 1946 as a part of post-war reconstruction, to provide a national university with a specific focus on international engagement, especially in the Asia-Pacific. It was founded as a research only university supporting research students, with undergraduate studies only commencing in the 1970s. From this history, the ANU has a strong research and international focus. As of 2017 it employed 1,710 academic and 2,398 professional staff (ANU 2017a). In 2016 the ANU supported 11,633 undergraduate, 9,073 postgraduate coursework, and 2,858 postgraduate research students across seven discipline Colleges (ANU 2017b). Key student demographics at an undergraduate level, where this study is focused, are provided in Table 1.4. In 2016 the ANU had 913 students enrolled in broad engineering and related technologies subject areas (Department of Education and Training n.d.). International students are charged full fees for courses, while domestic students are charged at a capped cost set by the Federal Government. Financial assistance is available to domestic students through a loan-scheme, HECS, allowing students to complete a degree by deferring payment until they start earning above a minimum income threshold. As engineering at ANU is accredited by EA it enables a common language and framework for the consideration of approaches and findings from this educational setting and context to potentially be applicable for other programs and institutions in Australia.

Table 1.4: Demographic profile of ANU undergraduate and engineering programs with national comparisons. Data is current enrolments with ANU % *from ANU (2017b),* national % *taken from Universities Australia (UA 2017), and* ANU Engineering % *and* National Engineering % *from Department of Education and Training uCube 2016 Data for Engineering and Related Technologies (Department of Education and Training (n.d.)) although * is for all university enrolments not only undergraduate (due to data availability).*

Demographic	**ANU % (2016 Data)**	**National % (2015 Data)**	**ANU Engineering % (2016 Data)**	**National Engineering (%) (2016 Data)**
Part Time Study	15.8	33.9	9.2	15.9
Female	51.5	57.9	22.0	16.2
Aboriginal or Torres Strait Islander	0.6	1.3	n/a	0.39*
Low Socio-Economic Status	2.4	14.6	n/a	n/a
International	22.4	≈22.0	39.6	29.6

1.3.3 Educational Setting

Engineering studies at the ANU are located in the Research School of Engineering (RSEng) within the College of Engineering and Computer Science (CECS). RSEng was established at the end of 2010 through the merger of the School of Engineering, which was a traditional teaching and research department, and a dedicated engineering research school. As of the start of 2018 it had 108 academic staff across four research themes; Energy, Fabrication, Information and Materials (CECS 2018). The Bachelor of Engineering (BE) at the ANU commenced in 1990 and was conceived as a contemporary engineering degree. In addition to the BE program, a specialist BE(R&D) has been developed. This provides a PhD pathway with higher entrance requirements and additional research projects for students from 2nd year. Both programs are 4-year long honours programs that are EA accredited. The student profile at the undergraduate level is shown in Table 1.4 alongside indicators for the ANU as a whole. As can be seen, engineering students are mostly full-time and less diverse than the ANU as a whole apart from a high percentage of international students.

The BE and BE(R&D) programs are both four years full-time, formally consisting of 192 units of credit. As a typical semester long course is six units of credit, a standard degree consists of 32 courses. A full-time study load is four courses of six units of credit each. All engineering students at the ANU undertake a common core, then branch into specialist majors from 2nd or 3rd year. This provides an opportunity to embed content and topics within core courses making them available to all students regardless of major. A final year semester-long group design project and year-long individual research project provide opportunities for substantial service-learning. Special topic shell courses are available in semesters and summer and winter sessions which can be used to trial and test new courses without requiring full academic approval. The two degree programs (BE(R&D) and BE) are within a single School and administrative structure, providing greater visibility of opportunities to staff and students.

The single School and common core provide opportunities to capture a specific student profile for each year level, enabling comparisons to HumEngEdu initiatives and experiences as required for the research questions. The multiple opportunities for engagement through project work, service-learning and special topics contributed to the research design, which enabled data collection to be linked to specific courses and topic selection (see Section 1.5).

1.4 Previous Research

In order to investigate the research questions posed, existing research was examined. Specific previous research is discussed in each chapter and publication where it is most relevant but a number of articles that supported the overarching research design are discussed here. These generally focused on HumEngEdu and related areas, the curriculum approaches used, and involvement with EWB (in all cases below this is EWB-USA only). However, research from broader areas in engineering and higher education were examined. These identified a range of potential themes and findings that could emerge within the context of this study, and elements have been incorporated where relevant.

1.4.1 Project-Based Service-Learning Studies

An assessment approach for project-based service-learning (PBSL) was described in Cummings et al (2013) for the EPICS (Engineering Projects in Community Service) program at Purdue University. EPICS is one of the longest established service-learning programs in the USA, with the approach and model adopted in multiple institutions. At Purdue, the approach is service-learning (SL) as it is specifically for course credit. Evaluation of the program covered individual student learning, team and project performance, community impact and the program as a whole. Cummings et al (2013) outlined all these but focused on data collected from program alumni. This utilised a mixed-method approach combining a 63 question survey with a subset of interviews drawn from survey respondents. Survey questions covered undergraduate involvement with EPICS and other volunteer and extra-curricular activities, work since graduation, and civic engagement. In addition to the survey questions, suggestions for data collection were provided including association with engineering (identity) and nationality. In terms of outcomes, the data highlighted the role of PBSL in preparing students for engineering practice as well as recognising the role of engineering as benefitting society.

In another study exploring the impact and influences of EPICS, Huff et al (2013) investigated how graduate alumni of the program made sense of design within engineering practice. The research study utilised an embedded sequential mixed-methods approach with an emphasis on qualitative data. Quantitative data collected assisted in the sampling strategy for qualitative interviews and provided support for findings from interviews. From a survey of over 500 alumni, sampling for interview participants first consisted of an extreme case strategy focused on participants who had identified significant learning through EPICS, followed by a maximum variation strategy across demographics, employment and involvement with EPICS. This led to 27 interview participants who undertook semi-structured interviews. Guiding questions included memories of EPICS, frustrations with the program, and benefits from other studies that EPICS did not provide.

Interviews were conducted by one of two researchers with participants being interviewed by the researcher they least associated with EPICS. This was in order to ensure alumni could share frustrations with EPICS and provide an open critique to someone they did not link with the program. A systematic thematic analysis was applied to interview transcripts, with a particular focus on design from which three keys themes were identified. While the specific outcomes and themes are not as relevant for this research, the study approach and methods provide relevant detail to assess the impact of service-learning within engineering with a particular focus on a defined outcome space, which in Huff et al (2013) was *design for engineering practice*. The use of systematic thematic analysis allowed the researchers to explore participant responses without the need of an existing theoretical framework and while not attempting to develop a new theory.

Pierrakos et al (2013) investigated student cognitive and affective learning outcomes and gains from a two semester-long second year (sophomore) design projects. In developing their study approach, the researchers argued quantitative surveys only depend on student self-assessment and do not link to course performance, while qualitative data collection only cannot typically be generalised. A mixed-method study was considered appropriate in order to support generalisation, validation, and detailed outcomes in metacognitive and affective domains. A concurrent triangulation design was utilised so that data and analysis from multiple sources could be triangulated in order to provide more confidence in the findings. Quantitative and qualitative data was collected in parallel (although in practice this was sequential), analysed separately, and then integrated as the last stage of the study. Three cohorts of students were tracked over two academic years. Quantitative data were collected from surveys with 12 elements linked to US ABET criteria a-k (technical outcomes), with a total of 54 five-point scale questions. To provide further details, three open-ended questions were used to collect qualitative data. Thematic network analysis was used to code the open-ended questions, with two researchers coding independently line-by-line. From this, 13 themes in five categories were identified, with an inter-coder agreement of 85%.

As noted in the study limitations of Pierrakos et al (2013), the small sample size was a concern. Over the two-years of the study, 34 students were present at each sampling point. Of these, 92% were Caucasian and 77% male, but this could have been representative of the student cohort as a whole, although this was not discussed. All elements in the data collection were self-reported, which allowed for anonymous collection. However, the relatively small amount of qualitative data collected (three questions) from 34 students potentially provides a limited data set. Data was collected during the activities and projects, without the opportunity for students to reflect on their learning and connect with other aspects of their studies. The study highlighted it would be of benefit to compare the results with a comparison group which did not undertake PBSL.

1.4.2 Studies Involving EWB-USA

In a large study, Litchefield et al (2016) sought to directly compare skills of engineers involved and not involved in engineering service to the broader community. This utilised EWB-USA as the means by which engineers could become involved with engineering service. Again, a mixed-methods study was utilised, specifically an exploratory sequential approach. However, this differed to the studies above in that primarily qualitative data was collected first through interviews and focus groups, followed by a large quantitative questionnaire. This meant what was "taking place" could first be identified from the rich qualitative data, then tested and potentially generalised through a larger and more diverse sample population. To support the analysis a critical realist perspective was used. This recognises multiple partial yet still valid perspectives for a single complex reality. In turn, this supports greater validity of findings through multiple methods and analysis of those realities.

Over 18 months, 32 focus groups and 27 individual interviews with engineering students and practitioners were conducted, 105 participants were involved with EWB-USA and 60 were not. Interviews and focus groups were semi-structured, covering predetermined themes but allowing for deviations where considered important by the researchers. These were coded for emergent themes related to participants' learning outcomes across technical and professional skill domains, based upon ABET outcomes a-o. Key findings from this initial stage of their research were technical skills were comparable between those involved with service (through EWB-USA) and those who were not, although the former group may have applied those skills earlier. However, for professional skills, those involved with service had greater opportunities to experience and apply them than those without a service component to their learning.

From these initial results, a questionnaire was developed linked to ABET a-k outcomes and CASEE's (Center for the Advancement of Scholarship on Engineering Education) outcomes 1-0. The final questionnaire consisted of 45 questions grouped into 15 outcomes with two to four items per outcome , which used either a five-point ("none" to "high") or four-point scale ("not at all" to "always"). Almost 3,000 responses were received (at a response rate of 2.5%), which was reduced to just over 2,500 after removing incomplete responses. ANOVA, Bonferroni-adjusted t-tests, and multiple linear regression models were used to analyse the responses and allow for potential variation due to underlying differences. Results from the quantitative analysis were then compared to qualitative findings to produce the overall research findings. This found graduates had similar technical skills development, but there were differences in professional skills between those involved with service, who were able to articulate the additional complexities in engineering work. This was due to having had opportunities for extended learning through experience with "realistic, contextualised and complex engineering projects". The conclusion found "engineering service experiences appear to contribute to engineers' higher confidence and perceptions about their own PS (professional skills), yet without compromising their TS (technical skills)". This potentially supports the hypothesis in this research, that engagement with HumEngEdu, which incorporates a focus on service, could produce engineers with better graduate outcomes across the breadth of all engineering skills and competencies.

Although based on ABET and CASEE outcomes, further graduate learning outcomes were identified by Litchefield et al (2016) that were not defined in these frameworks. This suggests the analysis for this study should provide for as wide an opportunity as possible for students participating to articulate outcomes from their HumEngEdu experiences, not only those linked to EA stage 1 competencies (the Australian equivalent of ABET). Their research also highlighted challenges collecting and comparing data from both students and practitioners. One approach to overcome this would be to focus on a more specific cohort such as final year students or recent graduates.

Another study with a focus on EWB-USA, but a student chapter at a single institution, is Berg et al (2016). This outlines a methodology for capturing and evaluating the impacts of humanitarian service-learning projects supported by a student chapter of EWB-USA, with an aim of improving students' experience and outcomes for future practice. It identifies a pool of potential data sources, including national EWB-USA documentation and surveys, and data from the local project and chapter, such as surveys, interviews and ethnographic field work. Data from students not involved in EWB-USA projects is suggested to be collected to provide a comparison. The research proposes collecting additional data from the international partner community, which they recommend be completed by social science students using ethnographic approaches.

Summarising the methodology for other researchers, Berg et al (2016) stress the need for a mixed-methods approach, allowing for a rich set of data sources with the potential for greater understanding of the student experience and overall learning outcomes. They suggest research data collection should include four key elements: pre- and post-surveys; interviews; field observations; and data collection from a comparison group not involved with the project. As a limitation, the paper only provides the planned methodology, no results are presented, and further work at the time of this research outlining the success for otherwise of Berg et al (2016) has not been identified.

1.4.3 Research on Student Learning

Plett et al (2011) explored student connections to their learning communities and attitudes to class (study) and professional identity. First, a conceptual model based on existing research and literature linking students' connections to community with academic and affective outcomes was developed. The model incorporated academic engagement, professional identity, and belonging, from the classroom to the university as a whole. A survey was developed to test and validate the model. Drawing from existing work, this included items to measure students' connections to campus, identity items for their discipline, and affect items towards their learning. Results from the survey indicate senior STEM students connections to the classroom, discipline major and university, correlate with their career identity and positive attitudes in class. As with previous studies, the survey results were further explored through focus groups with a sub-set of student respondents (although that aspect was not covered within the work). A recommendation from the study is to adopt a mixed-method approach to explore study programs as to when, where and which communities contribute to students' sense of community, impact on their identity, and engage STEM students in learning.

Numerous studies have provided factors that could shape student influences, engagement and outcomes from HumEngEdu and LTS in general. Canney and Bielefeldt (2015) developed a "professional social responsibility development model". This was based on interviews and data collection from engineering students and graduates. The model included eight dimensions, the most relevant of which for this study were personal social awareness, professional development, professional connectedness, costs/benefits and action. A survey was conducted using the model to evaluate students' development of social responsibility. Litchfield and Javernick-Will (2015) identified a range of stronger personality traits, greater motivations for positive social impact, and broader interests for members of EWB-USA compared to non-members. They also suggest self-efficacy could provide insights into why engineers become involved with, or have an interest in, social engagement.

Other studies have utilised individual and collaborative visual methods to assess programs and collect data. To explore the range of LTS programs and their characteristics, Bielefeldt et al (2013) used large sheets of paper and post-it notes to gather data from participants. During a two-day workshop, 35 participants placed post-it notes along scales, or spectra, of 15 distinct features in four categories used to characterise LTS programs: foci; design; management; and academic. Each spectrum was divided into four segments to represent the range of potential responses, scaled from "none" at one end to "high" at the other. The location of all the post-it notes was then collected to provide data on the range of LTS programs for the 15 features. Notable results were: extra-curricular (non-course credit bearing) activities were most often international experiences and not subject to rigorous course assessment; high levels of staff support resulted in greater civic outcomes; and international contexts can draw greater attention to social and cultural challenges than is evident to students working domestically.

Pasque et al (2009) used a grounded theory methodology to explore student created pathways integrating curricular and co-curricular (or extra-curricular) activities to achieve participation in a diverse democracy. The resulting theory identified four pathway pattern groups that students created. These could be visualised over 4 year study programs, with various activities taking place in each year. This is very similar to the potential pathway developed in this research which integrates for-credit and extra-curricular activities. This approach could be used with students in interviews or focus groups, to have them to visually map their engagement with HumEng over their degree programs.

1.4.4 Summary

The research critiqued above is summarised in Table 1.5 which highlights factors that may be significant to capture from students and the potential forms that data collection can take. These include attitudes to study, self-efficacy, extra-curricular engagement, and international experiences. These factors are incorporated into specific data collection methods used in this study, noting the benefits, limitations, recommendations and relevance for the focus here, its specific research questions and geographical context (outlined below in the following section). Many of the studies also focus on, or at least include, project-based service-learning with these two curriculum approaches are often used in combination.

Table 1.5: Summary of major existing works reviewed to inform the study design with specific details provided where available.

Study	Focus	Methodology	Data Collection	Findings
Cummings et al (2013)	Impact of PBSL.	Sequential mixed-methods.	523 survey responses followed by interviews of 27 alumni.	PBSL prepares students for engineering practice.
Huff et al (2013)	Design within engineering practice.	Embedded sequential mixed-methods.	Over 500 surveys followed by 27 interviews of alumni.	Three separate views of design within engineering practice.
Pierrakos et al (2013)	Impact of PBSL.	Concurrent triangulated mixed-methods.	34 second-year engineering students.	PBSL can contribute to engineering competencies but needs scaffolding at second year.
Litchfield et al (2016)	Impacts of involvement in engineering service.	Exploratory sequential mixed-methods.	32 focus groups and 27 interviews followed by over 2,500 survey responses of students and graduates.	Engineering service contributes to greater development and perceptions of professional skills.
Berg et al (2016)	SL projects in EWB-USA student chapter.	Mixed-methods will multiple data sources.	Documentation, surveys, interviews, ethnographic field work (proposed only).	Not available.
Plett et al (2011)	Links between professional identity and study.	Conceptual model tested through mixed-methods.	Survey of 287 participants across five universities.	Connection to classroom and major correlate with career identity and positive attitudes in study.
Canney and Bielefeldt (2015)	Development of social responsibility.	Conceptual model developed through mixed-methods, applied through survey.	1000 engineering students and graduates.	A model to assess development of social responsibility attitudes and beliefs.
Litchfield and Javernick-Will (2015)	Involvement in engineering service.	Exploratory sequential mixed-methods.	27 interviews and 32 focus groups of student and professional members of EWB-USA and non-members then 2,167 survey responses.	Role of self-efficacy, personality traits and interests for motivations for positive social impact.
Pasque et al (2009)	Student participation in diverse democracy.	Grounded theory.	23 current student participants.	Four distinct student created pathways integrating curricular and extra-curricular experiences.

It is of interest to note the contemporary nature of these studies, all occurring since 2013. As mentioned in Section 1, HumEngEdu has only emerged since the 1990's, and only even more recently in Australia. HumEng, the curriculum approaches and experiences that support student learning, and its impact on professional practice and engineering outcomes is a contemporary topic. There is particularly the case in Australasia, where there is a significant gap in existing research of the area in Australasia. There is limited research investigating HumEngEdu and the common curriculum approaches in other countries such as service-learning and study abroad. What research there is has focused on the single initiatives, often EWB-A programs including the EWB Challenge (Jolly 2014, Cutler et al 2010) or EWB Undergraduate Research Program (Smith et al 2009). The is a lack of research in Australasia exploring how HumEngEdu is embedded with engineering degree programs and the impacts for students from multiple engagements with it. It is here that this study is focused, and highlights the significance and contributions of the research particularly for the area in Australasia.

1.5 Research Inquiry

To build on the existing research in the previous section, potential research methodologies for this study were examined. These were drawn from the works above as well as Case and Light (2011) and Creswell (2003) to determine the overall research design and framework. The latter two both refer to Crotty (1998) which is indirectly considered from these later works.

Creswell (2003) provides three prompts to shape a research design:

1. Knowledge claims made by the research including a theoretical perspective (research characteristics).
2. Strategies of inquiry (methodology and research design).
3. Data collection and analysis methods (data collection procedures, methods and analysis).

These are used as a framework for this study, to assess and describe the research design used here, addressed in the following three sub-sections. A further sub-section is provided that examines the impacts and implications of the selected research design.

1.5.1 Research Characteristics

Overarching beliefs, characteristics and assumptions must be made explicit as a starting point for research inquiry. From Creswell (2003), which looks at research in general, and Jolly et al (2013), which is specific to engineering, this study takes a constructivist approach to knowledge. The research considers students' outcomes and experiences as the end-result of their education. Curriculum design and delivery are part of the research as they were required to shape a new pathway for students to engage with and experience. Students engage with the resulting HumEngEdu pathway in different ways, in terms of the number and type of engagements. The first element of engagement can be readily measured through student numbers and enrolment, whereas the type of engagements and resulting student experience and outcomes are different for each student. The experience will be constructed by students based on their previous experiences, beliefs and worldviews. This aligns with a constructivist approach. This supports the research aims and design of this work, as discussed below.

More recent than positivist and constructivist claims, pragmatic knowledge claims for research have emerged. Within Creswell (2003), pragmatic claims allow for choice during a research study as the work evolves, data is collected and analysed, and participant experiences emerge. It provides for a wide variety of data collection tools and methods. Pragmatic claims still acknowledge and recognise the social constructs of the research context but allow for further flexibility at the level of detailed data collection. However, a constructivist view was still considered most relevant to this research due to the focus on student outcomes and use of qualitative data.

1.5.2 Methodology and Research Design

1.5.2.1 *Research Strategy*

Building from the context of this study and its motivations, aims, and scope, a mixed-methods strategy was deemed the most appropriate to address the research questions posed. A mixed-methods strategy was considered more favourable than a specific single strategy from only a quantitative or qualitative perspective. Formally, mixed-methods research is a form of study where “quantitative and qualitative research techniques, methods, approaches, concepts or language” (Johnson and Onwuegbuzie 2004) are combined, or mixed, within a single research study. It seeks to legitimise the use of multiple data collection and analysis methods as a way of providing research methods that can best answer the research questions posed. In this way it generally takes a *pragmatic* philosophy that is shaped by the research at hand. However, as it includes qualitative data, a constructivist claim is common, building from that tradition, as is the case here.

The opportunities and methods enabled through a mixed-methods design support the goals of this study as the first to explore engagement with multiple HumEngEdu initiatives in Australasia. It is an exploratory study designed to allow key themes or findings to emerge. Previous studies, particularly in the USA, have identified a number of potential themes and outcomes from HumEngEdu and related areas, and the common curriculum approaches they utilise. This has included impacts on understanding of social response (Bielefeldt and Canney 2014) and ethics (Berg et al 2016, Bielefeldt et al 2016), the understanding of global awareness or practice (Litchfield and Javernick-Will 2014, Bratton 2014, Lam et al 2016), and a higher than average representation of females (Bielefeldt et al 2009, Litchfield and Javernick-Will 2014).

However, as highlighted in the context for this study (Sections 1.1.1 and 1.3), the Australian setting provides a number of differences across HumEng understandings, educational delivery, history, and development priorities. These differences mean existing overseas research instruments and findings cannot be used in exactly the same manner (as highlighted previous in Section 1.1.5). Previous international research provides alternatives for starting to explore potential themes, approaches and outcomes, but a research design needs to allow significant findings to emerge from the different contextual setting. Again, a mixed-methods approach allows this, supporting tools and methods based on previous findings to guide initial data collection design across both quantitative and qualitative sources. Based on ongoing analysis, areas of most interest can be explored in more detail using appropriate data collection tools.

The mixed-methods approach supports the evolving nature of the research here, with the design, delivery and evaluation of HumEngEdu occurring simultaneously. To support data triangulation and potential ethical and data reliability concerns (addressed in more detail in Section 1.5.3), multiple data sources are required. Quantitative data from student enrolment, demographics and evaluations is required to address some of the research questions (in particular question 2). Similarly, emerging trends from interviews can be used to shape surveys to determine the scale or nature of a specific experience or outcome. For example, from early data on demographics, there was a substantially higher percentage of females participating in optional HumEngEdu experiences. This finding could then be explored in more detail during interviews.

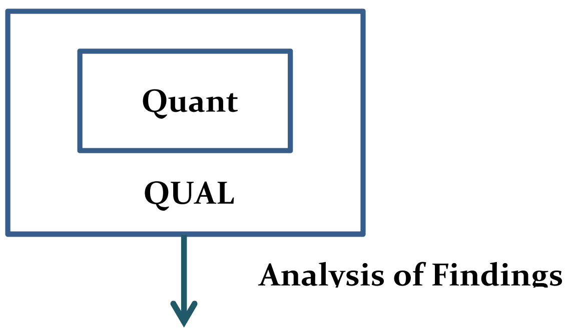


Figure 1.3: Representation of the nested concurrent research strategy. Based on the style and terminology in Creswell (2003).

From the requirements of the research, a concurrent nested strategy was adopted, shown in Figure 1.3 following the conventions and style of Creswell (2003). The strategy continuously collects quantitative and qualitative data from multiple sources throughout the study. The research merges quantitative data of student engagement from enrolments, demographics and surveys, with detailed qualitative data drawn from written submissions, interviews and focus groups. The nested concurrent strategy allows quantitative data to capture student profiles but focuses data collection at later year levels and graduates through richer qualitative interviews and focus groups. The most significant component of this research was exploring student outcomes from engagement with HumEngEdu, which required a distinctive student voice to be captured. For these reasons, the emphasis is on the qualitative data, with the quantitative data nested within the predominantly qualitative data collection.

The nested approach aligns well with the HumEng pathway developed, where students self-select as they move through the various activities during their studies. Greater numbers of students are involved and can be reached through quantitative methods in earlier initiatives, while a smaller number of students complete multiple elements of the pathway, allowing qualitative methods to be used to explore their entire experience. The nesting supports the research questions of the study, with the embedded quantitative elements focusing on the first and second research questions, while there are qualitative aspects to the first and third research questions, the latter of which requires greater data collection from a wider variety of methods. Integration across quantitative and qualitative data will occur predominantly during analysis, where the data sources allow. Other integration will occur during interpretation where analysis from more disparate sources can be combined.

1.5.2.2 *Alternative Strategies*

Alternative research methodologies, in particular drawing on discussions in Creswell (2003) and Case and Light (2011), were considered but ultimately not adopted for the study. Action research was reviewed due to the researchers' intimate role in creating and delivering HumEngEdu both with EWB-A and the ANU. Action research provides a structured framework for continuous reflection and evaluation of education innovations and changes. It can actively involve participants within the action being sought, which maps well to an education context, encouraging students to engage in the design and evaluation of education and hence foster student ownership. However, action research tends to focus on fostering social change and altering social practices (Case and Light 2011). This did not align with the aims of the research, although it could have been used to examine broader social changes that HumEngEdu may contribute to engineering education and practice.

Grounded theory was evaluated, which provides an emphasis on theory development (Strauss and Corbin 1994). Categories, themes and theory are developed directly from the data, not existing concepts or hypotheses (Charmaz 1996). It has a focus on processes, with data collection and analysis progressing simultaneously (Charmaz 1996). In this way data collection and analysis shape further work in the study. Grounded theory has been used as an approach to explore student learning and outcomes. Komives et al (2006) used grounded theory (as described in Komives et al 2005) to develop a leadership identity development model which consisted of three key stages across six categories. Walther et al (2011) applied the approach to focus groups of 67 students across four countries to look at the influences that contribute to engineering students' formation of their professional identities. A contextual model of competence formation was identified with five educational influences acting as inputs, and three types of learning outcomes as outputs of the system. While the emergent focus of grounded theory, rather than relying on existing concepts of hypotheses, is relevant for this study, the research here did not seek to specifically develop a new theory. Rather, outcomes were to help share and inform further curriculum development within the context of the study and potentially similar programs in Australasia.

With the focus on the student experience in this study, ethnography was another methodology considered. This focuses on observation, using formal and informal methods, of members of an identified group (Case and Light 2011). Ethnography would have provided an appropriate tool set and supported the nature of the research with developing and delivering HumEngEdu initiatives and approaches. If the focus on the study was on the engagement between HumEngEdu students and external partners or communities, such as achieved through EWB Summits and SL projects, this could have been appropriate. However, the regular turn-over of students during the research makes it difficult to observe a single group. Further, the study was focused on the outcomes students identified from their engagement and less about their cultural identity as someone involved in HumEngEdu. It could be that this identity and the culture around HumEngEdu is identified as a key outcome or motivator for students, in which case a further dedicated ethnography study could be valuable.

1.5.3 Data Collection Procedures, Methods and Analysis

Within the selected mixed-methods strategy, numerous data sources, collection tools and analysis methods are required to address all the research questions and support data triangulation and validity of findings. The studies discussed in Section 1.4 highlighted a range of potential data sources and collection approaches. As a starting point for a detailed research design, the potential data sources with respect to students are explored below.

1.5.3.1 *Participants*

Participants are drawn from the undergraduate BE and BE(R&D) programs within the Research School of Engineering at the ANU. Specific courses for data collection are provided in Table 1.6.

Table 1.6: Courses which provide opportunities for participants and data collection at the ANU.

Code	Name	Year	Requirement	Offered
ENGN1211	Discovering Engineering	1st	Compulsory for BE, BE(R&D)	1st semester every year
ENGN2225	Systems Engineering Design	2nd	Compulsory for BE, BE(R&D)	1st semester every year
ENGN2226	Systems Engineering Analysis	2nd	Compulsory for BE, BE(R&D)	2nd semester every year
ENGN2706	Engineering Research and Development Project (Methods)	2nd	Compulsory for BE(R&D)	1st semester every year
ENGN3221	Engineering Management	3rd	Compulsory for BE, BE(R&D)	1st semester every year
ENGN3230	Engineering Innovation	3rd	Compulsory for BE, BE(R&D)	2nd semester every year
ENGN3712	Engineering Research and Development Project	3rd	Compulsory for BE(R&D)	Over 2 semesters, every year
ENGN3100	Practical Experience (zero credit unit)	Any	Program requirement for BE, BE(R&D)	Outside course units, program requirement
ENGN3200	Engineering Internship	3rd, 4th	In place of ENGN3100	Any term or semester every year
ENGN4200	Individual Research Project	4th	Compulsory for BE	Over 2 semesters, every year
ENGN4712	Engineering Research and Development Project	4th	Compulsory for BE(R&D)	Over 2 semesters, every year
ENGN4221	Systems Engineering Project	4th	Compulsory for BE, BE(R&D)	1st and 2nd semesters every year
ENGN4520	Engineering for a Humanitarian Context (EfaHC)	3rd, 4th	Elective for BE and BE(R&D)	Summer and winter terms every year

Students from both degree programs undertake common core courses in each year. All students complete final year individual research and group design projects, although the specific course, learning outcomes and credit unit value can vary between BE and BE(R&D). Further research projects are undertaken by BE(R&D) students in their second and third years. All students could potentially be involved with a study-abroad experience, work experience placement or internship with a HumEng focus. Depending on specific programs and elective spaces, all engineering students could complete the Engineering for a Humanitarian Context (EfaHC) course as part of their studies. These common degree experiences form the basis of data sources for the study.

1.5.3.2 *Data Sources*

The various data sources, their forms and corresponding courses are shown in Table 1.7. From courses, available data includes assessment items, which would be completed regardless of this study, and student surveys such as student profile and course entry- and exit-surveys. The number of HumEng related projects and assignments is available to be collected, to give an indication of engagement. Upon completion of degree requirements, students can be interviewed on their overall experiences and engagement with HumEngEdu. This sits outside a course structure, but final year research and group projects provide an avenue for identifying potential candidates. Similarly, focus groups can be run outside of a course and structured around an individual engagement or topic. Involvement in certain courses and initiatives provides identification of a suitable pool of candidates.

The final source of data is publically available material including media or news articles, interviews, or blogs. Such articles can be drawn from numerous sources including university marketing, involvement with student groups, clubs or societies, or external organisations. This data is not considered as reliable as other sources due to the potential focus, which may be on marketing or recruitment typically only portraying positive experiences and those that align with organisational values. However, this information can be used to identify potential research participants, their experiences and pathways, and capture the broader opportunity as seen from a marketing and recruitment perspective.

Table 1.7: Summary of potential data source types and sampling for courses (S refers to semester).

Source	Type	Students		Participant Attribution	Timing/ Session
		All	HumEng Only		
ENGN1211	Year Profile Survey	Y		Anonymous	S1
ENGN2225	Number of HumEng Projects Year Profile Survey	- Y	Y -	De-identified Anonymous	S1
ENGN2226	Number of HumEng Projects Year Profile Survey	- Y	Y -	De-identified Anonymous	S2
ENGN2706	Number of HumEng Projects HumEng Survey	- -	Y Y	De-identified Anonymous	S1
ENGN3221	Number of HumEng Projects Year Profile Survey	- Y	Y -	De-identified Anonymous	S1
ENGN3230	Number of HumEng Projects Year Profile Survey	- Y	Y -	De-identified Anonymous	S2
ENGN3712	Number of HumEng Projects HumEng Survey	- -	Y Y	De-identified Anonymous	S1
ENGN3100	Number of HumEng Projects Assessment Items HumEng Survey	- - -	Y Y Y	De-identified De-identified Anonymous	Year Long
ENGN3200	Number of HumEng Projects Assessment Items HumEng Survey	- - -	Y Y Y	De-identified De-identified Anonymous	Year Long
ENGN4200	Number of HumEng Projects Assessment Items HumEng Survey Year Profile Survey	- - - Y	Y Y Y -	De-identified De-identified Anonymous Anonymous	S1 and S2
ENGN4712	Number of HumEng Projects Assessment Items HumEng Survey Year Profile Survey	- - - Y	Y Y Y -	De-identified De-identified Anonymous Anonymous	S1 and S2
ENGN4221	Number of HumEng Projects Assessment Items HumEng Survey Year Profile Survey	- - - Y	Y Y Y -	De-identified De-identified Anonymous Anonymous	S1 and S2
ENGN4520	Assessment Items HumEng Survey	- -	Y Y	De-identified Anonymous	Summer, Winter

1.5.3.3 *Data Types*

From potential participants and data sources, multiple types of data can be collected for analysis. Written material can be drawn from course assignments and media articles. As highlighted, these both have alternative primary motivations but can support and trigger findings in combination with other data. A specific student voice can be captured through interviews and focus groups, providing primary data within a specific scope and focus. Combined written and oral data provide a rich source for evaluating the student experience and outcomes. To address some of the research questions, anonymous quantitative and short-answer open response surveys are required. These can be applied at any time but can be linked to specific courses depending on the target participants.

The variety of data sources and types again supports, and builds from, the selected mixed-methods approach. This strategy draws on the strengths of both qualitative and quantitative forms and allows a wide scope of data to be identified and collected. The variety of data available provides the greatest opportunity for themes and findings to emerge and supports data validity and triangulation. The data sources, types and when they are collected within the degree structure, are summarised in Figure 1.4. The data collection tools used are contained in Appendix II.

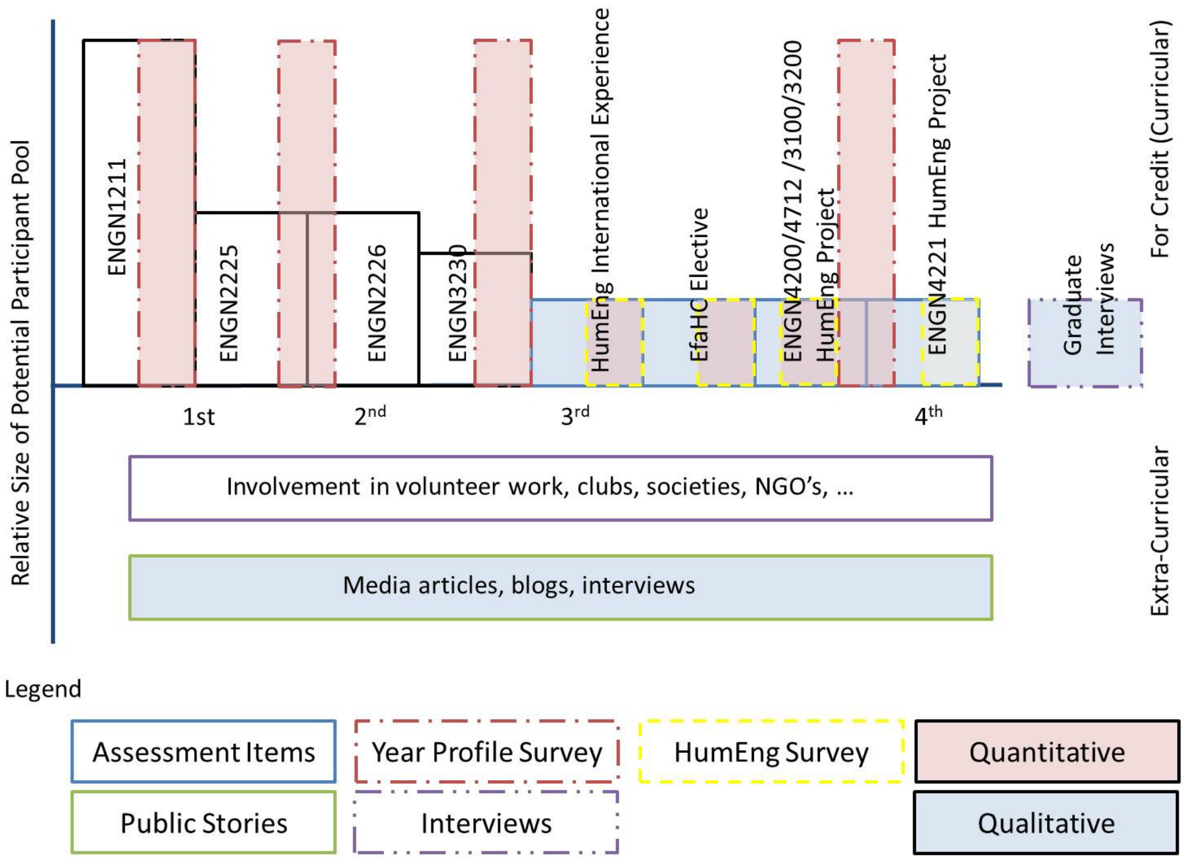


Figure 1.4: Overall data sources, timing within degree program, and form. Box outlines highlight the data source while shading indicators the predominant data form. Height gives an approximate indication of data size, with solid box outlines the relative amount of HumEng engagement compared to the overall cohort which is shown with a dashed line.

1.5.3.4 *Sampling Strategies*

Sampling strategies are opportunistic, predominantly linked to course and degree requirements to align with existing student availability and commitments. To capture overall student profiles, surveys were conducted within years (such as 3rd year), selecting one common compulsory course at the specific year level. Student profile surveys were taken at approximately the same point in a semester but could be either semester 1 or 2 depending on course availability. Student workload and experience should be similar at the same timing within either semester as the standard workload is four courses per semester. Surveys within courses and for specific experiences adopted a wide sampling strategy in that they targeted all students involved. EWB Summits and the EfaHC course run each summer and winter term, giving two opportunities per year to collect data. Research experiences which can include HumEng projects and topics can be started in either semester, and for final year student projects run over two semesters (or at least are valued as 12-units, twice a normal course). Similarly, BE(R&D) students can start research projects in either semester of 2nd or 3rd year. Final-year group design projects run for a semester and can occur in either teaching semester. Between the various research courses and the design course, there are two opportunities a year for students to start and complete projects.

Interviews with graduates utilise a targeted sampling strategy focusing on students who have had at least two optional engagements with HumEng. For example, this could include a dedicated course (EfaHC) and a research project. Extra-curricular engagements were considered engagement with HumEngEdu and could count as one option. The definition of two optional engagements excludes the EWB Challenge from the potential pool as this is compulsory for all students in ENGN1211 within which it is embedded. Further, undertaking the EWB Summit as part of the EfaHC course counts as a single engagement. Some students completed the Canberra-based version of EfaHC not involving an EWB Summit then separately participated in an EWB Summit, which counted as two engagements with HumEngEdu. Graduates were interviewed within 3 months of completing all their program requirements or graduation, whichever came first. Program requirements include the completion of 12 weeks of professional work experience, which in some cases is finalised after all the other degree requirements are completed. This means a student could be interviewed before their formal graduation, which occurs in July and December each year. Interviewing close to graduation minimises the potential differences in beliefs and learning due to professional practice, as highlighted by Litchfield et al (2016), although potentially some graduates will have significant exposure to work experience before graduation. Typically a block of interviews with graduates is completed twice a year following each of the graduations. Focus groups could be run at potentially any time depending on the topic, focus and participant availability, again utilising a targeted sampling strategy. Participants for focus groups were drawn from specific courses or from overarching themes and experiences, which would result in students from multiple year levels attending the same focus group.

For data collection embedded in courses, invitations and recruitment of participants was done in person during class time. Where surveys were undertaken, paper based surveys were used with class time set aside for participants to complete data collection. For interviews and focus groups, potential participants were sent an email invitation, with times then arranged for data collection. Potential participants were identified through known engagement, which was available through lists of final year research project topics, enrolment in the EfaHC course, and engagement in HumEng related study-abroad experiences. Responses rates are provided in individual publications where relevant.

1.5.3.5 *Data Analysis and Validity*

Interviews were recorded and transcribed, with the transcription used for analysis. Once collected, data was entered into NVivo or spreadsheets for storage and analysis. NVivo was used for qualitative data from interviews and assignments, in order to support coding. Quantitative data from surveys was entered into spreadsheets to allow numerical and statistical analysis. Typically anonymous quantitative data from surveys was first analysed independently of qualitative data. Qualitative data analysis drew from multiple data sources depending on the focus of the analysis. Quantitative and qualitative findings were integrated during analysis where possible, or in the evaluation of findings and interpretation of results to address individual research questions for the study.

Overall validity of findings was addressed through the mixed-methods research design itself. This allows for multiple data sources addressing the same questions and concepts. This is particularly relevant as quantitative data sources are anonymous while some qualitative data is collected face-to-face. As discussed in the researchers' role below, this has the potential to bias responses from participants, as highlighted in Huff et al (2013). The inclusion of anonymous data provides opportunities to validate the data across collection methods used. During qualitative data analysis in this study, multiple researchers are involved with coding and the identification of themes and emergent outcomes. Within the quantitative elements, large numbers of participants were sought in order to provide validity. Year-level profile surveys were conducted in-person with class time provided to complete them. Surveys for optional experiences were run over multiple years to provide a larger data pool.

Further details of the data collection and analysis procedures are contained in specific chapters. Chapter overviews are provided in Section 1.7 but Chapters 5 to 7 focus in detail on the data collection and analysis aspects of the study. At all times the requirements of the ethics protocols for the study were observed with respect to data collection and storage (see the Section 1.6.5 and Appendix I for specific protocols).

1.5.4 Impact of Research Design

The selected research strategy provides a number of benefits to support the study and appropriately address the stated research questions. However, it does provide certain implications and limitations. Creswell (2003) outlines a number of potential limitations and challenges for mixed-method studies and the concurrent nested strategy specifically. Most of the these relate directly to the choice of research strategy and the multiple data sources and resulting analysis required. These include extensive data collection across quantitative and qualitative methods, the resulting time and resource commitments required to achieve this, and the need to master multiple data analysis techniques. These impacts are all known at the time of selecting a research strategy and so with careful planning can be managed and minimised, and if mitigated, the benefits outweigh the limitations.

Other challenges identified by Creswell (2003) relate specifically to data analysis and the ability to draw appropriate findings and outcomes. This includes translating and moving between quantitative and qualitative results and the ability to integrate the two. This can be compounded if one data type is emphasised over another, as occurs in the research study here where qualitative data is the dominant source. As highlighted in Litchfield and Javernick-Will (2015), semi-structured interviews can be more challenging to code due to the breadth of potential responses. This mismatch can be addressed through good research design, examining previous studies for recommendations in data procedures to avoid challenges, and involving multiple researchers in the data analysis phase, which is a requirement to support data validity. Despite these limitations, the concurrent nested mixed-methods strategy was deemed the most appropriate for the aims, goals and context of this study and the research questions identified.

Within individual courses, data collected from students is either anonymous or de-identified. For students who engage in HumEngEdu through multiple courses this means a student could be asked the same question, such as "what do you consider humanitarian engineering?" multiple times. This is acceptable for qualitative analysis which explores the range of experiences, not the numeric distribution or most common. So if a student provides the same answer, it will not affect the results, and if an answer does change this is likely to be as a result of one or more experiences, in which case capturing this change is useful for the study. Similarly, students engaged in HumEngEdu will provide data through specific HumEngEdu experiences as well as overall student profiles at a year level. Again, this is required to ensure the overall student profile is as inclusive as possible so any comparison between a baseline and a specific HumEngEdu experience is as accurate as it can be.

1.6 Role of the Researcher

My role as researcher, creator, and deliverer of education initiatives, combined with my personal motivations and background, need to be highlighted to position myself within the study and its aims. These various positions and roles must be addressed to consider the ethical aspects of the research, both in terms of how it is undertaken and the influence on students within the educational initiatives developed.

1.6.1 Personal Motivations

I can remember the time and place where my view of engineering was transformed by humanitarian engineering (although that term was not used). I was attending the first EWB-A National Conference at the start of December 2005. I had joined EWB-A as a member earlier that year after attending a presentation at the ANU. Based on that presentation, I did not think that as a manufacturing systems engineer, *my* engineering could contribute to EWB-A's community development work. However, I agreed with EWB-A's vision and mission and joined as a way of showing support for the organisation which had only been in established in Australia two years earlier. I then attended the EWB Conference as something a bit different to industrial manufacturing. During the afternoon of the second day a presentation was given on a project to introduce solar cookers to a community in Malawi. The project used diffusion of innovations and technology transfer frameworks, the same research, approaches and methods I was researching and utilising in my work. A transformation was made: my engineering, any engineering, could be used to actively and consciously improve the daily quality of life of individuals, communities and societies. Engineering was no longer about technology, engineering was part of a complex system creating outcomes, including positive social benefits. Engineering could be "helpful". This started a journey exploring the intersections of engineering, education and development, which has become humanitarian engineering education (HumEngEdu). Eventually, this journey motivated me to study student engagement and outcomes in more detail. Why were students attracted to HumEng? Why did so many appear to achieve more significant outcomes than their peers? What were graduates taking away to their professional practice? These were the motivating questions for this study, to explore HumEngEdu and in particular the students engaging with it.

1.6.2 Professional Motivations

My professional identity is that of an engineer. Since graduating, I have always been a member of EA. However, I believe the role of engineers is changing and needs to. Engineers must consider and take responsibility for the outcomes and impacts of their engineering practice. This extends beyond delivering quality work on time to a paying client. It captures the engineers' broader role to the society impacted by their work. In the 21st century, where local decisions and technology can impact across national borders, this makes all engineering potentially global. If an engineer is not actively seeking to make the impacts and outcomes of their work inclusive and sustainable, then they are contributing to exclusion, inequality and un-sustainable practice. I believe these demands are captured in EA's competencies and code of ethics, but are not necessarily prioritised or incorporated into decision making. Much of this can be related back to an engineer's education where they are not given the tools, methods or even language, to consider and communicate these aspects of engineering practice. This is captured in a quote from (Ortega y Gasset 1961), "*when it dawns on engineers that to be engineers they need to be more than engineers*"

Engineering student cohorts and the profession in Australia, like many Anglo-centric countries, is not as diverse as it needs to be. It lacks diversity of lived experiences, perspectives, and ways of thinking. This gap impacts engineering, limiting its effectiveness and inclusion. The profession must seek to actively address this lack of diversity, as captured in EA's Code of Ethics (EA 2013).

Within professional engineering practice, I am motived to foster changes to education and professional practice, to make engineering more inclusive and considerate of social and environmental consequences and impacts. I hope the further development of HumEngEdu can contribute to this. HumEngEdu has the potential to provide tools and methods for engineers to consider the broader impacts of their engineering as well as approaches for making the process of engineering and its outcomes more inclusive. It is only by factors such as this that engineers can make positive contributions the achievement of ambitions such as the SDGs and NDIS.

1.6.3 Motivations for Impact

In completing this work, I am motivated to make contributions towards positive change in the world. My area of expertise and sphere of influence has come to rest in engineering education in Australia. I believe that all change involves some element of education. By innovating in engineering education I hope to create change in the engineering profession. By creating change in the engineering profession, I hope the benefits of engineering and technology can contribute to positive change globally. Although this work sits across development, engineering and education, it is embedded in engineering. The target audience is engineers, particularly those involved with education, as well as more broadly in professional practice. My aim is that the change championed by HumEngEdu will flow through to individuals and communities in Australia and beyond through more conscious and appropriate efforts of engineers. I believe that this change is justified and consistent with the agreed frameworks I operate within, in particular the SDGs and EA's Code of Ethics and Stage 1 Competencies.

1.6.4 Researcher Background

As identified in my personal motivations, I have been involved with HumEngEdu in Australia since 2005 with both EWB-A and the ANU. With EWB-A, I volunteered in a number of committee roles with the ACT Chapter, including two-years as Chapter President in 2007-2008. With the national office I first volunteered for two years and was then employed two-days a week during 2009-2010. My primary focus in this time was the development and implementation of the EWB Undergraduate Research Program. This engaged multiple community partners and university staff and students in SL HumEng projects. Other initiatives I supported while on staff included school outreach, the EWB Challenge, curriculum development and university partnerships. In other engineering roles, during 2017-19, I was a member of the Canberra Division Committee of EA.

At the ANU between 2011 and 2014 I delivered the first-year introductory ENGN1211 Discovering Engineering course that embedded the EWB Challenge. I have designed and delivered every offering of the Engineering for a Humanitarian Context course (EfaHC). I have acted as an academic mentor on one EWB Summit to Cambodia in January 2016 and the first delivery of the Enabled Future Singapore Study Tour with Enable Development in January and February 2016. I have supervised final year research projects and final year group projects on a range of HumEng topics since 2007.

At the ANU this means I have delivered many of the HumEngEdu initiatives and engagement students have had. For many of the graduating students engaged with HumEngEdu when the pathway was first completed in 2015, I delivered, supervised or coordinated potentially all of their engagement with HumEngEdu, except for the EWB Summit or their individual work experience. For such students, I was the course coordinator in their first year when undertaking the EWB Challenge, I was the course coordinator when they completed the EfaHC special topic, and I supervised or co-supervised their final year research project. Most students will have been exposed to other staff around HumEngEdu, through a project topic in core course, a different supervisor in final year projects, or through the EWB Summit. I have only been on one EWB Summit, and the group I was mentoring did not include any students from the ANU.

This direct engagement could impact on responses and data, particularly those provided through a student perspective such as assignment submissions and face-to-face discussions, as I conducted the interviews and focus groups for this study. Issues such as these were raised and discussed by Huff et al (2013), that close engagement between lecturer and researcher can limit the ability to receive direct responses during student interviews. My involvement with students could impede their confidence when addressing questions about limitations, gaps or frustrations with HumEngEdu initiatives and experiences as I would be able to attribute those to the student.

This potential limitation due to my involvement with student engagement in HumEngEdu at the ANU is addressed through the research design. Utilising mixed-methods from both quantitative and qualitative research traditions, and a combination of anonymous and de-identified collection, provides for triangulation of analysis and results. Ensuring students have a truly anonymous opportunity to provide a critique of the pathway and HumEngEdu engagement is required to provide unbiased data. Anonymous surveys allow this by capturing elements not stated in interviews and to ensure consistent results across the multiple data collection methods. The research questions were framed to focus on self-identified student gains rather than the course delivery and supervision. The collaboration with multiple co-authors across the publications is a further way of bringing external and independent review and critique.

As a further method to encourage input into the development of the pathway, particularly the initial EfaHC course delivery, students were made aware of the nature of the experience in that they were part of the first delivery of a course of this type in Australia. The need for robust feedback was stressed as was the opportunity for students to contribute to the growth of HumEngEdu in Australia. Most students took this seriously, understanding their role in piloting HumEngEdu.

1.6.5 Ethical Considerations

Following from my role in the research and previous work in HumEngEdu, a number of ethical considerations were identified which influenced the research design and approaches selected. The mixed-methods approach provides multiple opportunities for student input and responses, as well as the opportunity for students to *not* be involved with aspects of the research.

Many of the ethical concerns and considerations are addressed through approval of the research by the ANU Human Ethics Committee. The research conducted comes under two ethics protocols both of which are provided in Appendix I:

- ANU protocol 2015/389; the design and first delivery of the EfaHC course in 2015.
- ANU protocol 2016/550; an umbrella protocol covering research linked to specific courses and student interviews at or near graduation upon completion of their HumEngEdu engagement. Amendments were made by the researcher and approved by the ANU Human Ethics Committee a number of times as the research progressed.

Further ethical considerations were embedded in the development of new educational offerings to students. I had to be confident that the effort students committed to HumEngEdu experiences would contribute to the education outcomes they expect. Within engineering these are contributions to EA stage 1 competency standards and employability. Course material was constantly linked back to the EA standards to ensure expected educational outcomes addressed competencies. Further consideration and confidence was provided through discussions with designated authorities and academic roles within RSEng and CECS related to undergraduate engineering. In this case the academic approval processes and reviews provided assurance that courses and opportunities were deemed appropriate and relevant for the degree programs students were undertaking.

Another constant ethical consideration was appropriately engaging students in humanitarian action and development work and contexts. Previous work and studies, such as Schneider et al (2008) and VanderSteen et al (2009), had highlighted potential concerns with this. The latter considered the ethics of engaging students in humanitarian work by exploring the commitments of the parties involved and the outcomes and benefits received. There is significant potential that the educational outcomes for students, coming from a position of substantial relative privilege, can be the focus of experiences at the expense of significant resources and commitments by external organisations, individuals or communities.

To address this concern a partnership approach was adopted. External experiences or projects were through partnerships with community organisations, social enterprises or NGO's. Such partnerships enable multiple stakeholders to be involved in discussions and decision-making about experiences and engagement. It moves the focus from the educational institution to a collaboration involving the institution and organisation that aims to achieve sustainable and appropriate development and learning outcomes. Projects and initiatives only take place if benefits and value can be identified for all those involved.

Through this approach, partnering with appropriate organisations becomes the key decision. Partnerships must be based on shared values and common goals. The most significant of these partnerships is with EWB-A, but other partnerships are in place with other Australian-based organisations. These organisations have long-term relationships and partnerships with communities, individuals and potentially other organisations. This minimises risk for educational institutions and allows them to focus on academic core business.

1.7 Thesis Structure

This thesis is structured around individual publications. They follow the order of the research questions posed and the chronological order of the work undertaken. Each chapter contains a foreword to bind the chapters and establish the relationships between them and the overarching research aims, questions and methodology. These relationships between the pathway and research questions are shown in Figure 1.5 while Figure 1.6 provides links to specific research traditions across the mixed-methods strategy. The remaining chapters of the thesis and their relationships are described after these.

Chapters 2 provides background on HumEngEdu through existing international programs. It covers HumEngEdu's recent history and growth, definitions and understandings of HumEng, and curriculum approaches and initiatives utilised. Appendix III is a further publication detailing the understanding of HumEng in Australasia, which has in turn shaped the development of HumEngEdu in this work.

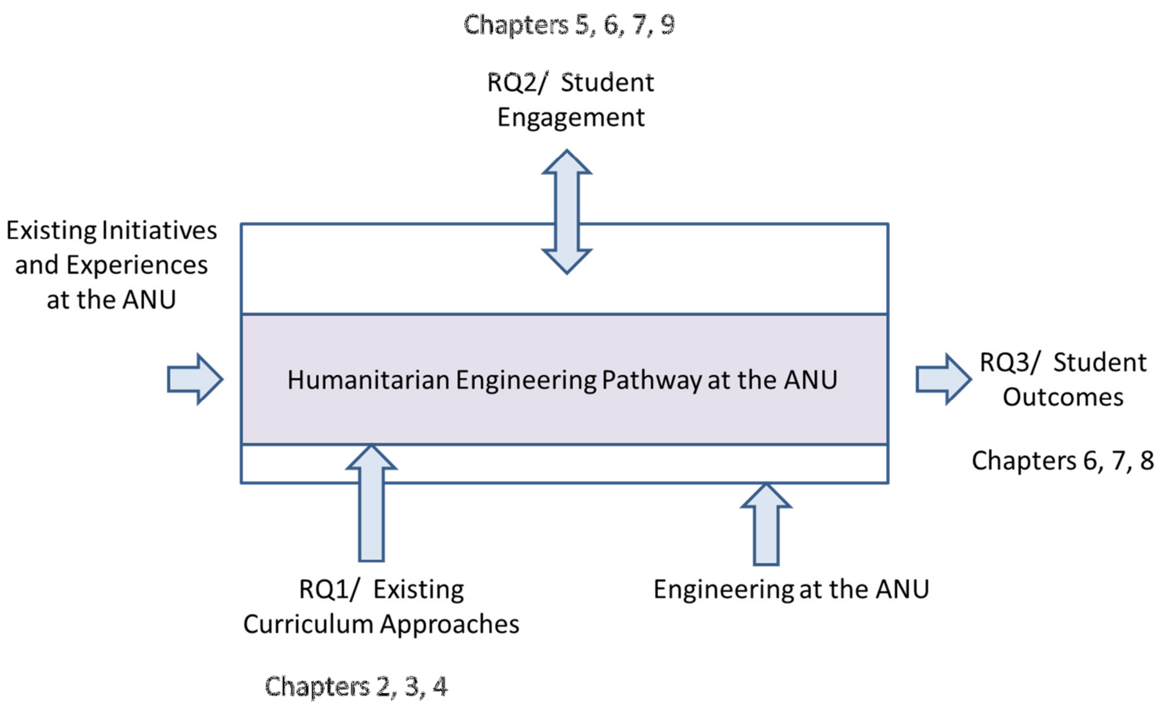


Figure 1.5: Relationship between the Humanitarian Engineering Pathway embedded in the engineering program at the ANU, specific research questions, and chapters where addressed.

Chapters 3, 4 and 5 describe individual initiatives within the HumEngEdu pathway developed at the ANU. They focus on the design, development and delivery of the Engineering for a Humanitarian Context (EfaHC) course and the inclusion of the EWB Summit within the engineering program at the ANU. The work detailed encapsulates the development of the HumEngEdu pathway completed in 2015 that addressed the first research question of this study, and provides a platform to investigate the second and third research questions.

Chapters 6 and 7 investigate student engagement with the HumEngEdu pathway and the student outcomes achieved. The second research question in this study, which focuses on student engagement with HumEngEdu, is specifically addressed in Chapter 6, which presents quantitative data collected through anonymous surveys. Chapter 7 focuses on the third research question, which looks at student outcomes from the pathway in terms of their knowledge of HumEng, and its impacts personally and on professional practice. Chapter 7 draws from multiple data sources, mostly qualitative. Both chapters provide details of data collection and analysis used. These chapters cover education delivered and data collected from 2016 to mid-2018. Lessons and recommendations captured within these chapters provide experience and recommendations for other institutions seeking to develop or enhance programs of their own. A Minor in Humanitarian Engineering resulting from the research implemented at the ANU is outlined in Chapter 7.

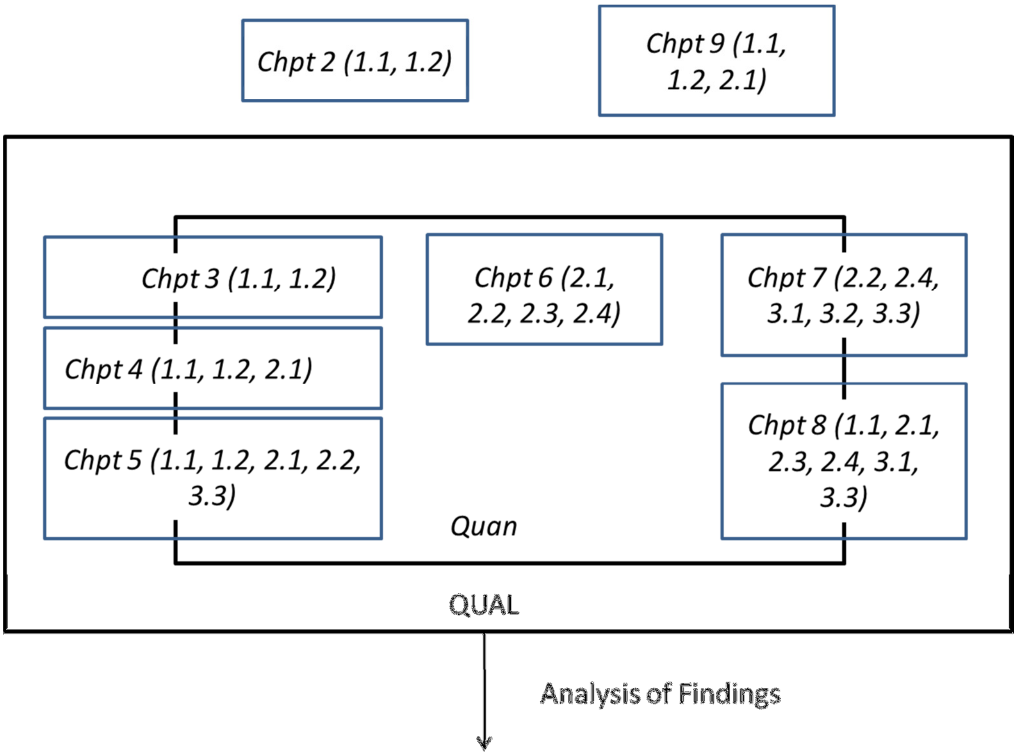


Figure 1.6: Relationship between research questions (in brackets), data sources and chapters of the thesis. Chapters that cross the Quan/QUAL boundary utilise elements from both research traditions.

Chapter 8 synthesises the previous chapters to outline a new program level design for engineering at the ANU. The lessons, evidence and outcomes identified in the rest of the work and all data collection methods are drawn together to a provide the design of program that seeks to abstract the lessons learnt in the HumEng pathway and apply them to a suite of integrated pathways within the core of the engineering programs. This uses the model and principles developed in the pathway to achieve greater learning for all students, in particular building from student motivations and interests.

Chapter 9 provides a summary of the recent growth of HumEng in Australasia, outlining the key organisations, education initiatives, and current and planned programs at universities in Australia and New Zealand. In particular it highlights the growth since 2015 in education offerings and student and university engagement with HumEngEdu. It covers the period of time this research was undertaken, and again highlights the role of this work as part of an area of rapid growth and hence in need of evaluation. It demonstrates some of the impacts of this research, being at the forefront of growth in courses and the EWB Humanitarian Design Summits.

Chapter 10 is the conclusion, and brings the individual works together and addresses the research questions posed. It explores the impact of the research through dissemination and on teaching practice and course offerings within the fields of study, from the educational setting through to HumEngEdu in Australia. Limitations of the study and research methodology are discussed as well as ongoing and further work. Finally, personal reflections on the research and its motivations will be discussed.

Appendix I contains the ethics protocols for the ANU Human Ethics Committee under which the research was conducted. Appendix II gives the data collection instruments for the research consisting of the surveys used and the script for semi-structured interviews with graduates.

Further publications for which the researcher was a co-author are included in the remaining appendices to highlight specific elements of the HumEngEdu pathway and this study. Appendix III is a paper containing results from a survey exploring the understanding of HumEng in Australasia which was a starting point for educational development in the area. Appendices IV, V and VI are first authored by students who engaged with the pathway, with Appendices IV and V authored by the first student to undertake all aspects of the completed HumEngEdu pathway. In this way, they represent the first humanitarian engineer by education, as opposed to experience, in Australasia. Appendix VII address some of the ethical considerations in the work outlining the partnership approach taken with community groups, specifically looking at the ANU and EWB-A collaboration. Appendix VIII is a position statement on HumEngEdu developed by ACED which outlines the growth of the area in Australia, and provides a set of priorities for further support and professionalisation. In many ways, this position statement represents the efforts of this work, to support the establishment of HumEng as a recognised area which can contribute to positive change for individuals, communities and the engineering profession in Australia.

Chapter 2: Review of Humanitarian Action and Development Engineering Education Programs

Foreword

To position the overall study within the field and existing work internationally, this Chapter presents a journal article detailing a review of higher education programs globally that have a focus or content related to Humanitarian Engineering (HumEng) and its education (HumEngEdu). The use of HumEng and other terms is explored, as, although only a name, this is critical to understanding programs and initiatives in place, their focus and emphasis, and the field internationally.

One of the key challenges identified in Chapter 1 was the breadth of terms, and even different understandings of the same term, used for engineering education programs with a focus on elements of the humanitarian-development spectrum in S1.1.1. In order to navigate these differences to assist with curriculum design and evaluation, particularly for the first research question (curriculum approaches necessary for HumEngEdu), a desktop survey of programs and initiatives within the broad umbrella terms was required.

The review undertaken starts with a summary of contemporary humanitarian action and development, as the two terms most commonly used to capture the spectrum of short- and long-term efforts. The historical role of engineering in these areas is summarised, going back to the 1980's when it first emerged in an identifiable way. The breadth of terms used is discussed, with terms including *humanitarian engineering*, *development engineering*, *engineering for development*, and *engineering in emergencies* all used, although with different understandings across, and sometimes within, individual countries (Appendix III provides a paper exploring the understanding of the term in Australasia). For the purposes of the paper, the phrase *Humanitarian Action and Development Engineering* is used, as this aligns most closely with established terms outside engineering.

A desktop study was completed to draw out characteristics from existing programs and initiatives at higher education institutions globally. This was used to identify program structures, support and foci. Key insights were the breadth and variation of programs, their approaches and even terminology. While this provides for innovation, creativity and flexibility, it can impact on the development of the area within the engineering profession. In addition, the paper highlights the need for national dialogue and discussion on HumEng and its understanding, education and practice, to ensure its long-term viability and to engage with professional practice and associations. One limitation of the study is the focus on the English-speaking world, particularly North America, the UK, and Australasia, due to the scope of English-language publications. This may have led to greater exclusion of programs in Latin and South America. However, as highlighted in the paper, the intent was not to provide a definitive list but explore the variation and common themes among programs.

Outcomes were identified to help shape the research in the overall study, particularly curriculum approaches, methods for integration of HumEng experiences, and understanding of overarching concepts. This helped to shape the design of the pathway at the ANU as well as provide guidance for comparison and dissemination of results and findings. In addition, the desktop study used to identify and describe programs provided a breadth of literature that was incorporated into rest of the research as required to address specific research questions and undertake curriculum development and education evaluation. While the research for this article commenced in 2016 (the second year of the study) there was a lengthy review process which meant the article was one of the last to be published from the thesis before final submission (in 2019).

EUROPEAN JOURNAL OF ENGINEERING EDUCATION
https://doi.org/10.1080/03043797.2019.1623179

Review of humanitarian action and development engineering education programmes

Jeremy Smith [a], Anh L. H. Tran [b] and Paul Compston [a]

[a]Research School of Electrical, Energy and Materials Engineering, The Australian National University, Canberra, Australia; [b]Faculty of Engineering, Environment and Computing, Coventry University, Coventry, UK

ABSTRACT

Numerous engineering education programmes internationally actively incorporate principles of humanitarian action and development, particularly aligned to the UN Sustainable Development Goals. To assess these, a review of 67 engineering education programmes and initiatives linked by the common goal of preserving life and alleviating human suffering was conducted to identify approaches used for design, support, delivery, integration and recognition. This found multiple designs and integration methods from short-term extra-curricular initiatives to dedicated award programmes at undergraduate and postgraduate levels. Numerous curriculum approaches were employed with project-based learning, study abroad and learning through service common. The breath of programmes, and various award and recognition methods highlight the need for institutions and countries to discuss methods and approaches to ensure both education outcomes and appropriate and ethical development practice. Three approaches are given for this, building from individual institutions to national discussions and professional recognition.

ARTICLE HISTORY
Received 14 August 2017
Accepted 18 May 2019

KEYWORDS
Development engineering; engineering for sustainable development; humanitarian engineering; qualification frameworks

1. Introduction and background

1.1. Contemporary humanitarian action and development

There is significant need for multidisciplinary practice that integrates resilience, sustainability, economics, development, health and technology for complex challenges including poverty alleviation and responding to natural and human-made disasters (Fiksel 2006; Allenby et al. 2009; UNDP 2014). Broadly there have been two sectors that work on such challenges, *humanitarian action* and *development*. The first traditionally focuses on short- to medium-term responses on a family or community level to external shocks such as natural disasters or conflict, while the latter typically considers long-term community development addressing vulnerability, disadvantage and marginalisation working across communities, states and institutions (OECD 2017). Both humanitarian action and development can be undertaken domestically and internationally. Contemporary development is primarily focused on the UN Sustainable Development Goals (SDGs), agreed to in 2015 with the aim of eradicating poverty by 2030. Within humanitarian action, the Sphere Project is one international framework used to improve responses and assistance across multiple actors and stakeholders, built around the *Humanitarian Charter and Minimum Standards in Humanitarian Response* handbook (Sphere n.d.).

Humanitarian action and development have common goals of preserving life and alleviating human suffering for those vulnerable, disadvantaged, marginalised or in chronic distress while

CONTACT Jeremy Smith jeremy.smith@anu.edu.au

maintaining human dignity and rights (UNDP 2014; Tayler 2016; OCED 2017). Both are complex, involving competing priorities, limited resources, time-pressures, and multidisciplinary contexts, with numerous failures and programmes that did not create ongoing benefits or outcomes (Vandersteen, Baillie, and Hall 2009; Nieusma and Riley 2010; Mazzurco and Jesiek 2014).

Although seen as two sectors, there is no clear distinction separating humanitarian action and development. Recent discussions have focused on the *nexus* between them and the need to build *coherence* across actors, stakeholders and funders with goals to build resilience to external shocks, reduce vulnerability and increase cooperation and alignment (Tayler 2016; OCED 2017). The World Humanitarian Summit in 2016 explored this challenge and renewed a focus on strengthening capacity of local people, institutions and states, recognising the SDGs will not be achieved without the ability to respond to external shocks (OCED 2017). This emphasised a focus on *collective outcomes* to meet people's needs, reduce vulnerability and enhance resilience.

To support education of practitioners and professionals in the humanitarian action and development sectors, numerous initiatives have been established. One recent example by the EUHAP (European Humanitarian Action Partnership) is the *Humanitarian Action Qualification Framework* (HAQF) provided through EUPRHA (European Universities on Professionalisation on Humanitarian Action) to support quality education and ultimately delivery of humanitarian assistance (Aardema and Muguruza 2014). In the development sector, the global Masters of Development Practice (MDP) offered through the Earth Institute at Columbia University represents just one of numerous award programmes. The MDP highlights the multidisciplinary nature of development, providing education in four specific science disciplines; health, natural, social, and management (Global Association n.d.).

1.2. Growth of humanitarian action and development engineering education

The role of engineering and technology has been present in humanitarian action and development for decades and is embedded within the SGDs and Sphere Handbook. While engineering is only explicitly mentioned once in the SDGs and targets, technologies such as energy and communication act as enablers or platforms to work in conjunction with other disciplines to achieve the broader goals. Similarly the Sphere handbook has technical chapters on shelter, non-food items, and water, sanitation and hygiene (WASH).

Such roles for engineering grew from the appropriate technology movement in the 1960s and 70s (Nieusma and Riley 2010), and started to explicitly emerge in the 1980s as demonstrated by the rise of dedicated engineering and technology focused community organisations. The first Engineers Without Borders (EWB) organisation, Ingénieurs Sans Frontières (ISF), was established in France in 1982 followed by organisations including national RedR's, other EWB organisations in Europe and Engineers Against Poverty (EAP) in the UK (UNDP 2015; Reed and Fereday 2016). Since 2000 further national EWB groups outside Europe as well as EWB International have been established along with Engineering for Change (E4C), Engineers for Overseas Development (EFOD), and Engineers for a Sustainable World (ESW). These have been established by students, academics and professionals and operate with a variety of missions and approaches (Cañavate and Casasus 2010; Meganck 2010; Paye 2010; Flower 2016).

The growth of these organisations preceded the establishment of education programmes in the area. Building from humanitarian action and development traditions, these use multiple terms including *humanitarian engineering* (Muñoz and Skokan 2007; Passino 2009; Campbell 2013; Kinsner 2014; Thomas et al. 2017; Baaoum 2018), *engineering for development* (Nieusma and Riley 2010), *development engineering* (Dzombak and Kramer 2017), *engineering for developing communities* (Amadei, Sandekian, and Thomas 2009), *technology for human development* (Pérez-Foguet, Oliete-Josa, and Saz-Carranza 2005), *engineering in emergencies* (Reed and Fereday 2016) and *engineering for sustainable development* (Fenner et al. 2005). In these, engineering and technology fuses with social science, resilience, economics and sustainability to provide programmes seeking to combine engineering with humanitarian action and development work (Bourn and Neal 2008; GDEE 2015). Such work specifically aims to bring engineering to meet basic human needs and enhance community and individual welfare in situations of chronic short- and long-term distress. From the established understandings of humanitarian action and development, for the purposes of this paper only, we shall collectively refer to such education and organisations as *Humanitarian Action and Development Engineering* (HADE).

The growth in HADE organisations and education has occurred as engineering education accrediting bodies shift to outcomes focused accreditation (Conlon 2008; Lucena et al. 2008; Moskal et al. 2008; Male, Bush, and Chapman 2010; Harsh et al. 2017). This defines exit standards for engineers and supports agreements such as the Washington Accord and Bologna Declaration which enable international mobility (Dowling and Hadgraft 2012). Accrediting degree programmes against frameworks can be centralised, with single accrediting bodies across disciplines as in Australia and the USA, or discipline specific as in the UK where 35 professional engineering institutions are licensed by the Engineering Council. Outcomes encompass broad skills for graduate engineers including explicit competencies for ethical practice, communication outside the discipline, sustainability and the global nature of engineering. Table 1 provides examples of these taken from four competency frameworks for countries with HADE organisations (EA 2011; ABET 2015; Engineers Canada 2016; FEANI 2016; ICE 2017).

1.3. Current research

The growth of HADE education programmes has been driven by factors including the need to equip engineers to work in the humanitarian action and development sectors (Amadei, Sandekian, and Thomas 2009; Berg, Lee, and Buchana 2016), increasing diversity in the student cohort (Muñoz and Skokan 2007; Bielefeldt, Paterson, and Swan 2009) and re-positioning engineering to emphasise social as well as technical outcomes (Bixler et al. 2014; Dzombak, Mouakkad, and Mehta 2016). Many are student-driven (Duff et al. 2014; Chisolm et al. 2014; Glade, Karter, and Pagilla 2014; Pinnell et al. 2014; Suhr et al. 2014) through organisations such as local chapters of EWB or ESW (Amadei and Wallace 2009; Dale et al. 2014) or learning through service (LTS) societies (Oakes et al. 2015). Programmes have been shown to meet the competencies in Table 1 such as ethics (Berg, Lee, and Buchana 2016; Bielefeldt et al. 2016), global practice, citizenship, awareness and practice (Litchfield and Javernick-Will 2014; Bratton 2014; Lam et al. 2016), and social responsibility (Bielefeldt and Canney 2014).

There has been substantial work on curriculum approaches for HADE education including LTS and problem- and project-based learning (PBL) (Dale et al. 2014; Dean and Van Bossuyt 2014; Oakes et al. 2015; Zoltowski and Oakes 2014). In LTS, students learn from the experience of providing a service for an external, typically community-based, partner. If this learning contributes to course credit it is termed service-learning (SL), otherwise it is considered extra-curricular when students receive no credit recognition (Bielefeldt et al. 2013; Tucker et al. 2013). SL has been shown to support student development of the competencies in Table 1 (Dika, Tempest, and Pando 2013; Bucks et al. 2015; Colledge 2014, Dale et al. 2014) and is often embedded into PBL courses due to the alignment between the aims, assessment and requirements of the two (Bielefeldt, Paterson, and Swan 2009; Duffy et al. 2011; Bucks et al. 2015; Oakes et al. 2015).

Previous studies have focused on education within a single institution, curriculum approach or definition of HADE education. There has been limited research exploring the breath of HADE education and its implementation within engineering programmes. Passino (2009) discussed the links between professionalism and service and highlighted the need for curriculum change, faculty drive and integrated support. Other works have critiqued programmes and their approaches (Nieusma and Riley 2010; VanderSteen, Hall, and Baillie 2010), partnerships and collaborations (Tayler 2016), and the need to professionalise the sector (Reed and Fereday 2016). To further these discussions, there is a need to review programmes and their structures and recognition across institutions and countries to understand the range and variety of programmes delivered and their relationships to engineering and the humanitarian action and development sectors.

Table 1. Representative competencies related to the broader context of engineering.

Country	Accrediting Body	Competencies
Australia	Engineers Australia (EA)	1.6. Understanding of the scope, principles, norms, accountabilities and bounds of contemporary engineering practice in the specific discipline. 3.1. Ethical conduct and professional accountability. 3.2. Effective oral and written communication in professional and lay domains.
Canada	Engineers Canada (EC)	*Communication skills*: An ability to communicate complex engineering concepts within the profession and with society at large. […] *Professionalism*: An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest. *Impact on society and the environment*: An ability to analyse social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship. *Ethics and equity*: An ability to apply professional ethics, accountability, and equity.
European Union	(Eur Ing) European Engineer with FEANI (Fédération Européenne d'Associations Nationales d'Ingénieurs)	5: Engineering Practice: (d) Taken account of the non-technical implications of engineering practice 6: Transferable Skills: (b) Used diverse methods to communicate effectively with the engineering community at different disciplines and levels as well as with society at large (c) Taken account of the health, safety and legal issues and responsibilities of engineering practice, the impact of engineering solutions in a societal and environmental context, and commit to professional ethics, responsibilities and norms of engineering practice
UK	Institution of Civil Engineers (ICE)	7. Sustainable Development A. A sound knowledge of sustainable development best practice. 9. Professional Commitment D. Demonstration of appropriate professional standards, recognising obligations to society, the profession and the environment. 4) E. Exercise responsibilities in an ethical manner.
USA	ABET	(f) an understanding of professional and ethical responsibility (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context (j) a knowledge of contemporary issues

1.4. Research questions

This paper provides a review of humanitarian action and development engineering (HADE) education programmes. It investigates:

1. The breadth of definitions used internationally.
2. The types and structures of HADE education programmes, the curriculum approaches used to deliver them, and how student learning is recognised.
3. Strategies to support the delivery of HADE education and goals.

The following section provides the methods used, starting with a discussion of definitions and terms. The results from the review of HADE education programmes identifies the range of programme foci, recognition, structure, delivery, integration and support. From these, discussion and recommendations related to HADE education and its delivery are provided.

2. Methods – review of humanitarian action and development engineering education

2.1. Definitions and understandings

Addressing the first research question, different terms are used for education programmes that intertwine engineering with established humanitarian action and development work. *Engineering for Developing Communities*, a term common in the US, refers to long-term international community development in developing countries (Parsons 1996; Amadei and Wallace 2009; Amadei, Sandekian, and Thomas 2009). *Development Engineering*, again used in the US, is similar but provides greater focus on interdisciplinary engagement, enterprises, and economic and product development (Dzombak, Mouakkad, and Mehta 2016). Reflecting this, the journal *Development Engineering*, established in 2016, has the sub-title *The Journal of Engineering in Economic Development*. *Humanitarian engineering* is a common term in which engineering and technology are combined with humanitarian responses and community development focused on populations considered underserved, under-resourced or disadvantaged, although this understanding does vary across countries (Muñoz and Skokan 2007; Passino 2009; Cañavate and Casasus 2010; Foster 2010; Campbell and Wilson 2011; Hill and Miles 2012; Leydens and Lucena 2014; Turner, Brown, and Smith 2015). In the UK, humanitarian engineering has generally referred to short-term disaster response echoing humanitarian action traditions (Hill and Miles 2012; Reed and Fereday 2016). In the US humanitarian engineering often focuses on long-term community development (Muñoz and Skokan 2007; Passino 2009). In Australia and New Zealand, it is considered to encompass the spectrum of humanitarian and development work from disaster response to community development, both domestically and internationally, hence differing from the traditional understanding of humanitarian action (Greet 2014; Turner, Brown, and Smith 2015). However, this understanding provides a greater emphasis on building community resilience and aligns with emerging approaches for coherence across humanitarian action and development (such as in OCED 2017). Engineers as far back as Cuny (1983) highlighted the intertwined nature of humanitarian action and development and how each must consider the influences and impacts of the other. Humanitarian engineering practice is supported by the *Journal of Humanitarian Engineering*, established by EWB-Australia in 2012.

The term *Engineering for sustainable development* takes a broader contextual emphasis than just developing, vulnerable or marginalised communities, examining the role of the engineer in all their work (Holmberg et al. 2008). This is common in Europe, along with initiatives which take a more multidisciplinary focus such as programmes exploring *technology and society* and *philosophy of technology*. This is reflected in changes to EWB/ISF organisations in Europe. For example, ISF Spain, which originated as a national association, changed its name ONGAWA (*Engineering for Human Development*) in 2011 (ONGAWA n.d.) to represent a broader mandate (although a Spanish Federation of EWB still operates) (ISF 2016). ISF France, the first established ISF/EWB, promotes the idea of a *citizen engineer*, reflecting a responsibility for engineering in sustainable development and reducing inequality in any location or context (Paye 2010).

Others have expanded on this responsibility and emphasise the role of social justice in achieving long-term positive change and impact beyond humanitarian action or development (Nieusma and Riley 2010; Leydens and Lucena 2014) while others have focused on engineering and peace (Catalano 2006). As highlighted in Vandersteen, Baillie, and Hall (2009), Nieusma and Riley (2010) and Schneider, Leydens, and Lucena (2008), engineering education programmes that incorporate humanitarian action and development must be critically evaluated to determine the contributions and benefits of all parties and individuals involved. This is critical as the privilege, resources and outcomes for students and their host institutions can potentially be placed before those of communities and individuals (Vandersteen, Baillie, and Hall 2009).

With numerous understandings, recent works have sought to provide umbrella terms in order to conduct research. Dzombak and Kramer (2017) use *development engineering* as a term covering humanitarian engineering, engineering for change, and engineering for impact without explicitly exploring the differences of approaches or understanding within these. Campbell (2013) uses *Humanitarian Engineering* for philanthropic focused programmes in 'community-service, disaster recover, and international development', adopting the term due to its widespread use and recognition. Nieusma and Riley (2010) use *engineering for development* to cover community development engineering, humanitarian engineering and appropriate technology, with a specific focus on community development work. Litchfield and Javernick-Will (2015) focus on the attention paid to engineering and social engagement, covering engineering and sustainable community development, humanitarianism, social justice and peace. They refer to combinations of these as *socially engaged engineering*. This does not draw from the traditions of humanitarian action and development, although it highlights engagement beyond the engineering profession. Education offerings using LTS have been explored (such as Bielefeldt et al. 2013), but this is a curriculum approach. However, reflecting the significance of this approach, the *International Journal of Service Learning in Engineering – Humanitarian Engineering and Social Enterprise* has been published since 2006.

As mentioned, for the purpose of this paper, Humanitarian Action and Development Engineering (HADE) will be used. This connects with the established traditions of humanitarian action and development into which engineering is seeking to be actively engaged. It provides an overarching distinguishing feature to identify programmes focusing on preserving life, alleviating human suffering, and enhancing individual and community welfare in any context faced with chronic distress or vulnerability. Specific terms will be referenced where they are explicitly used in other material.

2.2. Programme identification and inclusion

To identify the spectrum of approaches and variation among programmes a wide sampling method was used rather than attempting to create a complete list. Programmes were identified from published articles, summary sites of organisations including EfC and EWB at international and country-levels, media articles, university websites and web searches incorporating the definitions found.

To identify programmes for review, three criteria were selected:

(1) an identifiable programme within an accredited degree framework.
(2) an element of, or explicit link to, engineering.
(3) an emphasis on, or explicit link to, established traditions of humanitarian action or development focusing on human well-being, overcoming distress and disadvantage, or enhancing community welfare.

The first factor is a programme identifiable through its structure, outcomes or promotion within an institutional setting. This ranges from informal programmes such as LTS clubs and societies through to accredited qualifications. The search was limited to coursework programmes in higher education institutions, and excluded centres or organisations delivering training programmes or workshops that do not fall within professional accreditation frameworks. One-off initiatives or those supported by single individuals were excluded.

The second factor for inclusion was an explicit link to, or element of, engineering such as dedicated engineering courses or ownership by an engineering school, department or society. This excluded programmes within areas including the humanities or development studies such as the MDP which does not include a dedicated focus on engineering or technology. Although available to students through electives or double degrees these do not have any dedicated engineering element or link. We have excluded programmes focused solely on sustainability or ethical practice without any emphasis on development or humanitarian action. Global engineering programmes were included if they made specific mention of humanitarian or development work or developing countries (such as Lam et al. 2016).

The third factor incorporated established understandings of the humanitarian action and development sectors. This was a focus, emphasis or link to goals of preserving life and alleviating human suffering for vulnerable, disadvantaged or marginalised populations, ranging from short- to long-term, domestic or international.

Once programmes were identified, data was drawn from two sources, in order of priority:

1. articles in academic publications.
2. material available on university websites.

This supports the focus of the review to explore the breath of programmes and initiatives available.

2.3. Programme review

Each programme included was summarised using the descriptive elements in Table 2. These were based on research in HADE education and synthesis studies. VanderSteen (2008, 265) outlined a range of options that humanitarian engineering education could take from a single module for all engineers to specialisations and master's degrees. Similarly, Holmberg et al. (2008) provided course and programme strategies for embedding engineering for sustainable development in engineering at three European universities ranging from compulsory courses to specialised award programmes. Boni and Pérez-Foguet (2008) provided approaches that could facilitate the introduction of development education in engineering and found coursework options included elective and compulsory subjects, applied research or development projects, and practice in public and private enterprises. Study abroad opportunities are common within HADE education and Parkinson (2007) provided a range of approaches in engineering, from academic-guided group initiatives including SL, extended field trips and mentored travel, through to independent experiences such as internships or dual-degrees. Bielefeldt et al. (2013) examined LTS initiatives and the common methods used to design, manage and assess LTS but found 'no obvious best model'. A series of scales was developed for the inclusion of sustainability in engineering by Huntzinger et al. (2007) which identified alternatives as *bolt-on*, *built in*, or *rebuilt or redesign*. These referred to the amount of integration between the sustainability curricula and the base engineering programme, with *rebuilt or redesign* the most effective for student learning but requiring the greatest changes to curriculum and programme structures.

The *Program Information* and *Focus* was collected for every identified programme. If the programme met the three criteria for inclusion, the remaining information was collated drawing from multiple sources for each programme. Information collected was coded using themes identified from the research for curriculum approaches and definitions. From this, the variation in approaches used across programmes was identified.

Table 2. Elements used to review and analyse HADE education programmes.

Element	Description
Institutional Information	University, country, owning department, school or faculty.
Programme Information	Level (under- or post-graduate), award or recognition, year launched and pre-requisites.
Programme Focus	Context including geographic (domestic, international, both), sector (such as humanitarian, development, sustainability, global), and focus (for example technology, community, disaster).
Programme Structure and Delivery	Required courses, credit units, electives, and curricular approaches used.
Programme Integration	With other award programmes and administrative structures.
Supporting Centre	Support available through education programmes, research centres or student organisations.

3. Material – existing programs

Seventy-nine programmes were identified of which 67 ($N = 67$) met the three criteria for analysis. The complete list of the 67 programmes is provided in Table A1 in the Appendix which lists the articles used to characterise them. Figure 1 shows the cumulative number of identified programmes since 2000 still operating, where data was available on the year established. Only two pre-2000 programmes were identified, both launched in the late 1990s. Some institutions had historical opportunities or initiatives dating further back, but the year established is when the programme in its current form was launched. The establishment date of related organisations are provided for countries where programmes were identified.

Programmes are shown by region or country in Figure 2, grouped by non-award (non-qualification) programmes, and award undergraduate and postgraduate programmes (a programme at one institution was offered through two award programmes).

4. Results – design, implementation and delivery of programs

4.1. Programme focus

Figure 3 shows the focus and geographical distribution of programmes, with a description of each focus given below. Where possible programmes were grouped according to the term used at the institution rather than applying an external definition. This confirms the range of terms used and geographic understandings found, with a focus on disaster management in the UK, community development in the US, sustainable development in Europe and humanitarian engineering in Oceania.

Community development: long-term community development rather than humanitarian action or disaster response, typically working with community groups or NGO's. Each could have a geographic focus which was domestic (national) only, international (non-domestic) only, or an explicit focus on both.

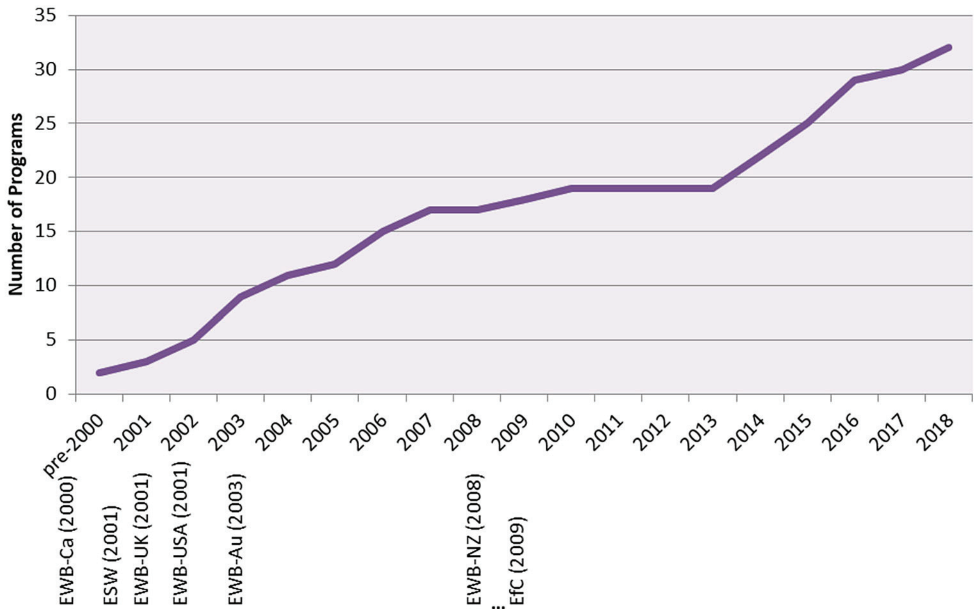


Figure 1. Cumulative number of programmes by year launched (where data available) since 2000 along with founding dates of related organisations for countries with HADE education programmes.

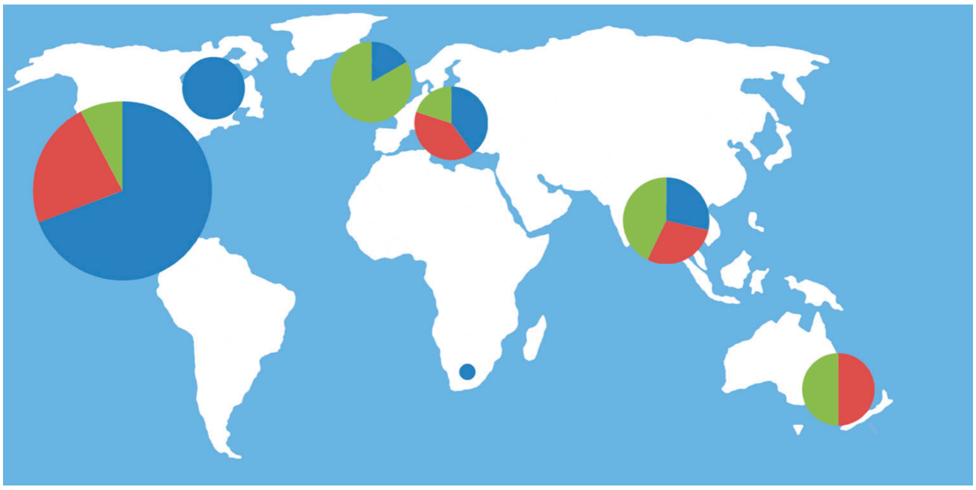


Figure 2. Number of non-award (blue), undergraduate award (red) and postgraduate award (green) programmes by geographical location (size indicates overall number relative to each other, the largest is 39 programmes, the smallest 1).

Technology development: an emphasis on innovation and entrepreneurship, including social entrepreneurship, within a developing or disadvantaged context which could be domestic or international. Focused on developing products and services and the business models to deliver them in a sustainable, particularly economically, way.

Global engineering: working on projects or in teams with an international reach or mindset (Lohmann, Rollins, and Joseph Hoey 2006; Jesiek et al. 2014) but not focused solely on development, disaster or humanitarian action.

Disaster management: from the tradition of the humanitarian action sector, encompassing disaster response, recovery, planning and preparation. Often had a technical focus on housing, water, sanitation or other infrastructure similar to the Sphere handbook technical chapters.

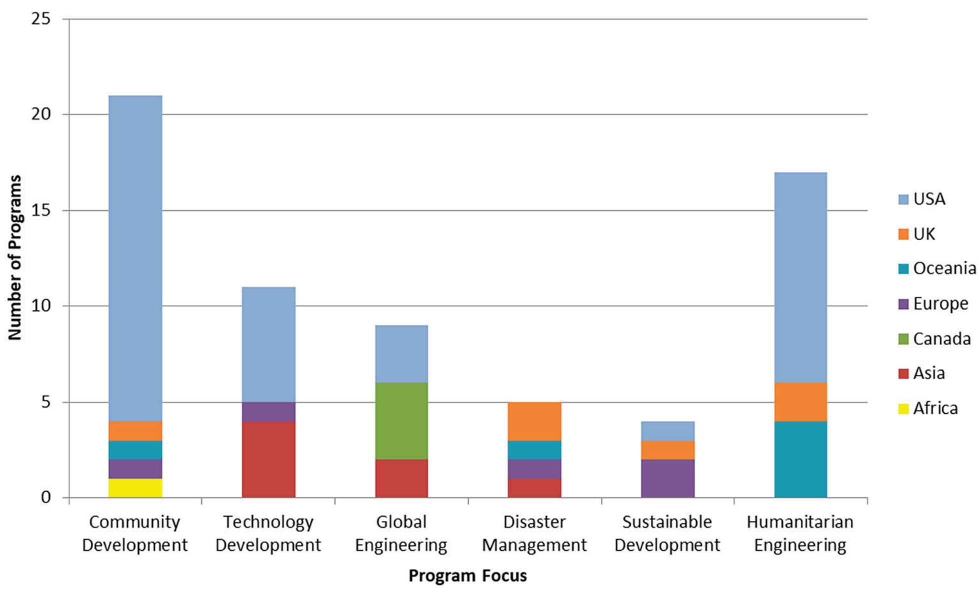


Figure 3. Identified programme focus and geographical distribution.

Table 3. Programme focus and emphasis or context elements for each (E is Essential, O is Optional).

	Emphasis or Context							
Programme Focus	Global	Local	Technology	Humanities / Social Science	Sustainability	Developing / Disadvantaged	Short-Term	Long-Term
Global Engineering	E		E		O	O		
Disaster Management	O	E	O	O		O	E	
Technology Development	O	O	E	O	E	O		O
Community Development	O	O	O	E	E	E	O	E
Sustainable Development	E	E	E	O	E			E
Humanitarian Engineering	E	E	O	E	E	E	E	E

Sustainable development: programmes with an emphasis on development balancing economic, social and environmental considerations. Generally referred to on a global level, with outcomes that could be applied in any country or region, developed or developing.

Humanitarian engineering: a combination of humanitarian action and development, both international and domestic, integrating sustainability and potentially product design and development.

Table 3 shows the range of programme foci with the emphasis or context that is considered *Essential* (E) and *Optional* (O) for each. Of the 67 programmes analysed nine had a specialist focus in a discipline or field such as WASH, earthquakes or energy. Six of these were at postgraduate level including *Infrastructure in Emergencies* at Loughborough University, *Earthquake Engineering and Disaster Management* at UCL, and *Earthquake Engineering* at Tokyo University. The remaining 58 programmes were generalist, building from a students' underlying engineering discipline and the breath of interpretations of humanitarian action and development.

4.2. Programme structure and delivery

A variety of structures were found for programme design and delivery including extra- and co-curricular initiatives, compulsory and elective courses and programme requirements. Curricular approaches and delivery methods including service-learning (Tucker et al. 2013), study-abroad (Parkinson 2007; Smith et al. 2016), PBL (Dean and Van Bossuyt 2014), internships (Ferrer-Martí, Garfí, and Ferrer 2015), capstone design projects (Bucks et al. 2015), research projects (Dzombak and Mehta 2013) and LTS (Bielefeldt et al. 2013; Oakes et al. 2015) were common. These were to provide a practice component for students, integrated into their studies depending on opportunities and resources available. Each approach dictates the assessment methods used and resourcing required.

Seven distinct overall programme structures were identified and are described below.

Extra-curricular: consisted entirely of extra-curricular activities or initiatives, with no credit bearing component and hence no assessment. It is possible such initiatives could contribute to programme requirements, such as mandatory service or work experience, but no dedicated course structure was used to support students. Programmes could be student or institution organised. Examples of this approach are *ETHOS* at the University of Dayton, *VESL* at Villanova University and the *SEADS* Programme at Princeton University.

Service-learning: similar to extra-curricular in that students undertake external experiences, but course-credit is provided for the experience as per the definition of service-learning (Tucker et al. 2013). This is typically through internships, research or capstone projects, with assessment aligned to those experiences. The *Community Project Module* at the University of Pretoria and the *Technology Development Supervised Learning Program* at the Indian Institute of Technology Bombay are examples.

Coursework only: incorporates only coursework without any dedicated external service-learning component. This was the least common approach, with an example being the *Disaster and Recovery Minor* at Wageningen University.

Coursework and extra-curricular: programmes where one or more courses, which could be a mix of compulsory and electives, are required along with an extra-curricular requirement. The latter could take the form of a volunteer placement, internship or study abroad experience. An example is institutional implementation of the *Global Engineering Certificate* from EWB-Canada which is focused on demonstrating competencies rather than formal assessment.

Course- and project-work: incorporates one or more compulsory courses along with required project work. Project work could take the form of senior design or capstone projects, individual research or honours projects, service-learning, study abroad or other PBL courses, but all for which a student receives course credit. This was one of the most common approaches with the *Graduate Certificate in Engineering for Developing Communities* at University of Colorado Boulder an example.

Single course, electives and project work: include a single dedicated compulsory course along with one or more elective choices, typically from a list or specific disciplines, followed by a project work requirement. This was one of the most common approaches for formal programmes such as minors or diplomas with examples including the *Humanitarian Engineering Minor* at Oregon State University and the *Diploma in Global Humanitarian Engineering* at the University of Canterbury.

Multiple courses, electives and project work: the programme consisted of multiple compulsory courses, a number of electives and project work. This was the most common structure for dedicated award programmes including specialist masters and substantial undergraduate programmes. The *Certificate in Engineering and Community Engagement* at Penn State University, *Humanitarian Engineering Major* at the University of Sydney and *Engineering (Humanitarian Engineering) Degree* at Arizona State University are examples.

4.3. Programme integration

The methods used to integrate HADE education into students' overall studies varied but in many cases were linked to the programme structure. Only one dedicated undergraduate degree was identified, at Arizona State University. Common at the undergraduate level were ways of integrating initiatives into students' programme through combinations of elective slots, extra-curricular activities and PBL courses as identified in the previous section. Six integration methods were identified, incorporating terms from Huntzinger et al. (2007):

Framework: an external framework is used such as the *Global Engineering Certificate* developed by EWB-Canada (Lam et al. 2016). This provides student flexibility, choice and ownership but is outside their award programme. It sets broad outcomes, suggested topics and experiences from which students' develop their own plan. Once complete, the student demonstrates their attainment, and if successful, is awarded a certificate. Some institutions made reference to the *NAE Grand Challenge Scholar Program* as a framework for students (WEFO 2015).

External: all the experiences are extra-curricular and not integrated into a students' study programme. Projects are run by student societies with many EWB-USA university chapters examples of this.

Embedded: experiences are embedded into existing course opportunities, typically through PBL courses and special topics. Such programmes generally do not lead to any qualification or formal recognition, but are a way for motivated students and faculty to provide a study opportunity, and could be characterised by terms such as track or pathway. Structures that incorporated project- or service-learning often employed this approach by providing topics and opportunities in the area via existing courses and their associated resource and assessment requirements.

Bolt-on: a more structured pathway added to a degree leading to a qualification or recognition, but not of an award common at the faculty. It may be the case that a certificate, specialisation or minor has been created for the programme, but there are no other options using the same administrative or award structure at the faculty. These typically involve one or two dedicated courses, then a range of existing electives and project-based opportunities.

Built-in: a programme within a defined faculty structure leading to an award or qualification, typically a minor or major. Institutions typically offer a number of such programmes to supplement a students' discipline. Integrating these has been the case of developing a programme with a HADE or similar focus within the established faculty framework.

Designed: a new dedicated award programme such as a named under- or -post-graduate degree, although potentially using existing individual units. This approach was used for specialist programmes.

4.4. Support centres

It was found that programme delivery could be supported through the following approaches:

Student-Led: support is through a student-led or run organisation. This was very common in the USA with student chapters of EWB-USA or ESW, while others had dedicated student organisations operating only at the one institution.

Education Support: provided by the home institution and purely education focused, with no independent research undertaken.

Discipline Centre: these operate across engineering disciplines, faculties or centres, and providing a focus for HADE education, including aligned research opportunities.

Research Centre: dedicated centres with a focus in the area with dedicated academic positions and projects. These often provided research opportunities for students at under- and post-graduate levels.

Approaches to support centres were found to vary between countries and regions. In Canada, programmes identified were part of the Certificate in Global Engineering, where the requirements of the certificate are set by an external organisation. In Oceania, dedicated support groups were uncommon and while there were EWB-Australia Chapters at major universities, none were leading projects as community project work is led only by the national office. In the UK, Europe and Asia, support was typically through discipline and research centres within the institutions reflecting a link to ongoing academic programmes. In the USA, institutional support centres were common, although these could be education, discipline or research focused. In addition, chapters of national organisations were more wide spread than other countries, with ESW and EWB-USA having 42 and 265 student chapters respectively (ESW 2018; EWB-USA 2019) while EPICS, a SL programme, operates across 29 universities in the USA (Purdue 2019).

5. Discussion

5.1. Growth of humanitarian action and development engineering education

The growth of HADE education is demonstrated in Figure 1. Two programmes established before 2000 were identified, with at least 16 launched between 2000 and 2009 and a further 14 since 2010 (to 2018 at the time of writing). While a number of European HADE organisations were established in the 1980s and 1990s (RedR and EWB/ISF group's in France, Spain and Belgium), there has been an increase globally since the turn of the century. This can be linked to broader changes including globalisation, changes to engineering competencies, and the Millennium Development Goals (MDGs). Launched in 2000 the MDGs had the overarching goal of halving poverty by 2015, which brought renewed attention to global disadvantage. Another increase in programmes has occurred since 2013, which could similarly be linked to the SDGs agreed to in 2015 to supersede the MDGs.

5.2. Programme emphasis

Programmes had a contextual geographical emphasis on domestic (national) work, international (non-domestic) work, or explicitly both, as shown in Figure 4. The number of internationally focused programmes in North America and Europe including the UK is likely linked to their historical roles in development and as global powers, as well as the recent emphasis placed on global engineering (Parkinson 2007). This historical background and concentration is significant when considering international placements to ensure the benefits are not focused solely on students as highlighted in Vandersteen, Baillie, and Hall (2009). Programmes can reinforce a mindset where development is seen as an 'overseas' activity, without the recognition of domestic challenges and disadvantage. This is where concepts of social justice should be incorporated (Leydens and Lucena 2014) or a focus on sustainable development as in Europe (Pérez-Foguet, Oliete-Josa, and Saz-Carranza 2005). The dual domestic and international programmes in Europe and the US highlight the emphasis of programmes on sustainable development, while the same focus in Oceania is due the understanding of humanitarian engineering that has emerged there across domestic and international contexts.

The recognition methods used and their frequency are shown in Figure 5. In Oceania, the focus is on parallel programmes that can fit into or alongside an existing undergraduate programme. This is seen globally with only nine specialist programmes identified, the rest focusing on the application of a specific underlying engineering discipline to humanitarian action or development work. In Canada, three of the four programmes identified build from the Global Engineering Initiative Certificate framework in place. The UK has a focus on postgraduate programmes, particularly MSc qualifications, which bring greater specialisation. The US focuses on undergraduate studies ranging from formal majors and minors through various certificate tracks or non-award programmes as well as extra-curricular only initiatives. In Europe the focus is award programmes with an emphasis on sustainable development, innovation and entrepreneurship, or the philosophy of engineering and technology. These differences broadly match the spectrum of understandings identified in Section 2.

5.3. Educational approaches

Most HADE education programmes have an experiential requirement such as PBL, LTS or study abroad. These can be challenging to mandate as they may involve travel or volunteer work. This impacts on the availability of programmes to students due to cost, commitment, or lack of availability of elective courses, as well as resourcing from the institution and ethical considerations (for example Vandersteen, Baillie, and Hall 2009). Some programmes did not have this requirement although a lack of field experience can be a potential gap for students wishing to undertake further opportunities in the area (Passino 2009).

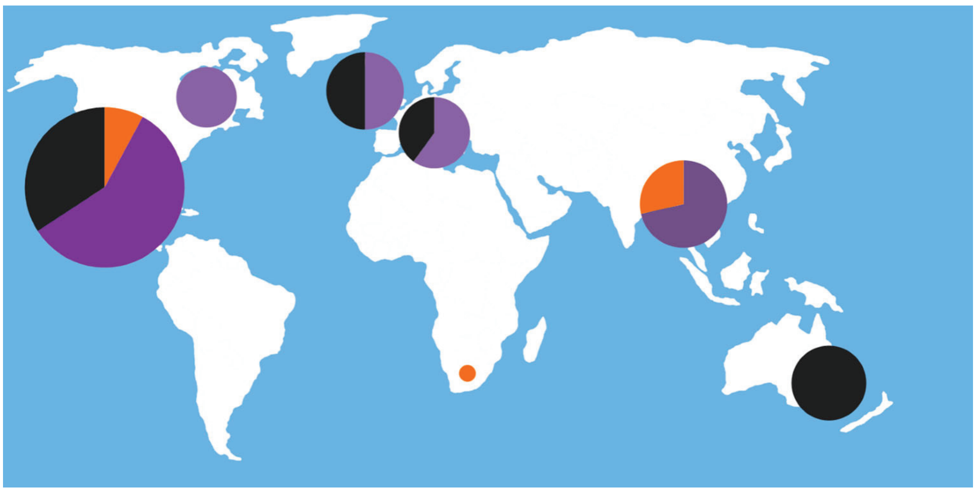


Figure 4. Geographical contextual focus of programmes (orange is domestic context only, purple is international context only, black are both) by country or region (size indicates overall number relative to each other, the largest is 38 programmes, the smallest 1).

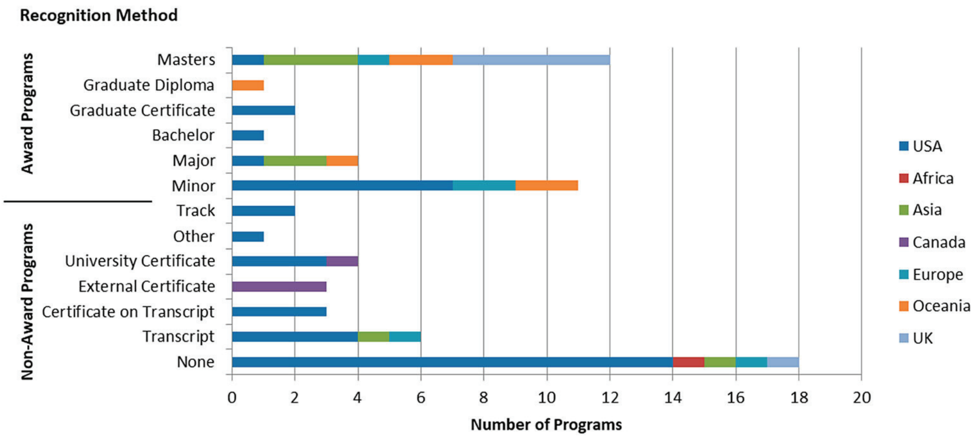


Figure 5. Recognition methods used for HADE education.

HADE education aligns well with the multidisciplinary SDGs and Sphere standards although this must be supported by a recognition of the need for interdisciplinary engagement. These aspects are highlighted in Muñoz and Skokan (2007) who state the need to administer, in this case humanitarian engineering, programmes with a multidisciplinary team encompassing engineering and social science. Other works highlight this cross-disciplinary engagement through a focus on social work (Gilbert et al. 2015; Walther, Miller, and Sockacka 2017) and development studies (Harsh et al. 2017). This emphasis was present in many of the programmes analysed, particularly the structured award programmes.

Given the requirements of PBL, LTS and study abroad, incorporating HADE education into an existing traditional engineering programme can be challenging and potentially inappropriate (Ferrer-Martí, Garfí, and Ferrer 2015) as well as requiring greater levels of supervision and commitment from staff and institutions (ACED 2018). The large number of non-award programmes (37 of the 67 programmes reviewed, or 55%) appears to indicate many are driven by student demand and motivated staff. Given this large number, many of the integration methods appear to be ways to provide opportunities to students and recognise their learning without an existing administrative faculty process available. This lack of formal qualification and university administrative structure is common for the embedded and bolt-on approaches, and are a potential concern for the long-term sustainability and viability of such programmes (Chisolm et al. 2014; Glade, Karter, and Pagilla 2014). Built-in and designed programmes demonstrate a greater level of commitment from an institution and are hence potentially more viable in the longer term (Huntzinger et al. 2007; Bratton 2014; Siniwski et al. 2015). They also have formal assessment tasks and structures unlike extra-curricular initiatives which are not for course credit and hence not directly assessed.

However, as embedded and bolt-on approaches typically lie outside formal award structures they often take advantage of newer educational approaches and delivery including opportunities developed by industry or practitioner organisations. For example, EWB-Canada has developed the Global Engineering Certificate which is used as a template by universities to implement a programme for students (Lam et al. 2016). EWB-Canada provides an online *Introduction to Global Engineering* course for students at institutions without subjects in the area. EWB-Australia has been supporting curriculum opportunities since the launch of the first year EWB Challenge in 2007 and EWB-Australia's initiatives are seen in all of the undergraduate programmes on offer in Oceania (Smith et al. 2017).

These education approaches are examples of education innovation and experimentation and an emerging trend of students taking advantage of a wider variety of learning opportunities. These include online courses (such as the *A Resilient Future – Science and Technology for Disaster Risk Reduction* MOOC (CODEV n.d.)) and extra-curricular activities such as LTS and study abroad.

5.4. Programme delivery and support

As demonstrated from the findings, there is a breath of programmes under a range of terms and approaches. The use of extra-curricular and informal experiences is wide spread, providing flexibility and innovation for students, staff and external organisations. However, due to the nature of development and humanitarian work this brings risks such as poor development practice, inconsistent quality control and lack of sustained outcomes (Vandersteen, Baillie, and Hall 2009; Nieusma and Riley 2010; Gilbert et al. 2015). Mazzurco and Jesiek (2014) completed a review of small- to medium-scale humanitarian engineering projects to develop a typology of common non-technical failures in order to enhance global engineering service-learning projects. From an assessment of eight case studies, they identified two failure modes, (1) *failure to learn*, related to the contextual setting, and (2) *failure to apply knowledge* even when contextual knowledge was gained. There were three sub-categories for the first mode, specifically failure to: assess the needs; understand the culture; and assess assets. These highlight the need for long-term partnerships and community engagement. Critiques and reflections of student-led projects identify challenges including the sustainability of student teams over multiple years, institutional barriers, access to mentoring and expertise, and communication (Ermilio, Clayton, and Kabalan 2014; Chisolm et al. 2014; Glade, Karter, and Pagilla 2014; Suhr et al. 2014). Dale et al. (2014), reflecting on the approach of ESW, highlighted the lack of mentorship and feedback present in extra-curricular experiences and the preference for projects to be credit-bearing, as well as the need for professional input into scoping projects.

These experiences demonstrate a number of potential gaps in knowledge or skills for HADE projects that are not part of existing engineering curriculum or competencies. The most common additional competencies or knowledge referenced are ethics, communication and engagement, and cultural immersion. While these align with competencies in Table 1, they need to extend beyond traditional engineering to applications to humanitarian and development contexts. Reed and Fereday (2016) highlight the ethical position of humanitarian work extends beyond the engineering profession and requires specific technical and contextual knowledge. Campbell (2013) argues for a framework of the *ethics of care*, while Walther, Miller, and Sockacka (2017) articulate the need for *empathy* based on social work. Within communication and engagement, specific approaches are necessary with Gilbert et al. (2015) and Harsh et al. (2017) identifying this as a gap within existing engineering education and delivering dedicated workshops to address it. Approaches such as Asset-Based Community Development (ABCD), are relevant (Mathie and Cunningham 2003) while Mazzurco and Jesiek (2017) identified five principles to foster community participation in humanitarian engineering projects. Cultural immersions through practical placements are highlighted (Passino 2009; Pinnell et al. 2014), with some research advocating for the need for both domestic and international placements to ensure an appropriate sense of social justice (VanderSteen, Hall, and Baillie 2010; Baaoum 2018). Community engagement training, cultural immersions and ABCD could go towards addressing the failure to learn modes identified by Mazzurco and Jesiek (2014). Many of the HADE programmes reviewed included specific content on ethics, communication and engagement, and cultural immersions, particularly those utilising a bolt-on, built-in or designed integration approach which typically involve for-credit experiences and courses. Access to such material can be more challenging for extra-curricular initiatives where dedicated university content may not be available.

5.5. Programme motivations and accountability

The recent growth in the area (Figure 1) highlights the need to ensure programmes are following appropriate and ethical development practice, balancing student needs with those of external partners and organisations. The need to provide additional content across the gaps identified above could be dependent on the motivation. For programmes focused on attaining engineering competencies such as those in Table 1 (highlighted by Litchfield and Javernick-Will 2014; Oakes et al. 2015; Dzombak, Mouakkad, and Mehta 2016; Lam et al. 2016), existing content and approaches could be satisfactory. As an example, it has been demonstrated that SL can lead to the development of engineering competencies, particularly professional skills (Dika, Tempest, and Pando 2013; Bucks et al. 2015; Colledge 2014). However, as highlighted by failure analysis, these may not be enough to ensure quality and appropriate outcomes for external groups and partners. When explicitly seeking to prepare graduates to work in humanitarian action and development contexts (such as Amadei, Sandekian, and Thomas 2009; Berg, Lee, and Buchana 2016), additional material that is not currently part of engineering education is required (Gilbert et al. 2015; Reed and Fereday 2016; Harsh et al. 2017; Baaoum 2018).

In all cases, accountability or quality review is required to avoid failures and poor development practice and outcomes (Amadei, Sandekian, and Thomas 2009; Dale et al. 2014; Davis et al. 2014; Siniwski et al. 2015). From research, three approaches for this were identified:

Institutional Review: programmes are reviewed and evaluated by institutions and incorporate best practice and guidelines. For example, Duff et al. (2014) highlighted the need to use external best practice which could include Engineering in Emergencies (Davis and Lambert 2002) or the principles in Mazzurco and Jesiek (2017). This needs to be within for-credit courses and experiences rather than extra-curricular, which sit outside academic review processes (Bratton 2014; Siniwski et al. 2015).

External Accountability: achieved through involvement in national organisations such as EWB-USA and ESW. These have central review processes and guidelines which engage professional engineers and provide structures for project and technical review and advice (Dale et al. 2014; Sacco and Knight 2014). These provide formal mechanisms for feedback for extra-curricular initiatives (Chisolm et al. 2014) although these do come with administrative and financial overheads (Duff et al. 2014).

Professionalisation: where the field is recognised and maintained by national frameworks, through engineering accrediting bodies or relevant associations. This was proposed for humanitarian engineering (linked specifically to humanitarian action) by Reed and Fereday (2016) who highlight the need to move away from programmes and practice that are only seen as volunteer based and identify potential competencies to work in the area and hence drive quality outcomes. The Australia Council of Engineering Deans (ACED), a peak body representing engineering education in Australia, developed a dedicated position paper on Humanitarian Engineering Education which proposes a similar need (ACED 2018). Dedicated agreed competencies can support employers, enable professionals to benchmark themselves to identify skill and knowledge gaps, and provide assurance for communities and partners (Dean and Van Bossuyt 2014; Reed and Fereday 2016).

A key requirement for all three approaches above is the need for discussion and research to create a shared understanding of practice (Hill and Miles 2012). One approach that aims to ensure quality practice which could be used as a model is the Humanitarian Action Qualification Framework (HAQF), provided through EUPRHA (European Universities on Professionalisation on Humanitarian Action) developed by the EUHAP (European Humanitarian Action Partnership). Finalised in 2014, this qualification competency-based framework was developed to support the education of humanitarian professionals across multiple institutions (Aardema and Muguruza 2014). It consists of eight levels with knowledge, skills and responsibility, and autonomy indicators for each. This aims to provide quality assurance for practice in the field, starting from a shared understanding of the aim of humanitarian action. This is consistent with the focus on collective outcomes at the humanitarian-development nexus (OECD 2017). As highlighted in Reed and Fereday (2016), HAQF focuses on generic humanitarian themes although these serve as a starting point for the requirements of humanitarian organisations. The HAQF could be a potential framework for HADE which would enable universities to articulate outcomes for graduates regardless of whether they have a formal award programme or not. A framework for HADE similar to HAQF could capture the multidisciplinary focus of the SDGs and humanitarian action while providing detail on the role of engineering and technology. This embeds principles of coherence to avoid a disconnect between humanitarian action and development, as highlighted by Greet (2014) who provided a *continuum* of humanitarian engineering, ranging from immediate emergency response through to long-term development to address disadvantage and marginalisation.

An alternative sector-wide approach is a collaborative process such as *Define Your Discipline* (DYD) described by Dowling and Hadgraft (2012). This would engage stakeholders and identify specific and agreed graduate outcomes to which programmes can be designed. This approach has been applied to a number of engineering and non-engineering disciplines as a way of providing detail to generic graduate competencies such as those in Table 1 (Dowling and Hadgraft 2012). This process emphasises the application of competencies to specific contexts, which could support the breadth of humanitarian action and development sectors highlighted in Reed and Fereday (2016) and Greet (2014). Another approach is the nesting of learning outcomes for programmes of different durations as described for humanitarian engineering education in Moskal and Gosink (2007).

6. Recommendations and conclusions

6.1. Recommendations for programs

HADE education needs to be appropriately integrated into students' studies rather than a single or standalone approach. This needs to balance opportunities for experiential learning with access based on cost and commitment to students, staff demands, and ethical considerations for external practice. To provide a HADE education programme that will enable a graduate to operate within the humanitarian action or development sectors, students' need to be exposed to education material from engineering, multidisciplinary HADE and the broader humanitarian and development context including appropriate approaches for ethics and engagement and communication. Multidisciplinary studies must be covered to understand the complexity of development and the SDGs in particular, as found in programmes with a focus on sustainable development, such as in Europe. Integration and institutionalisation of HADE education should not necessarily preclude further innovation and experimentation in the area. However, new initiatives need to be effectively evaluated including both student experience and outcomes as well as considerations for partners, communities and appropriate humanitarian and development practice. Such evaluation would also enable successful and beneficial approaches to be shared and scaled.

6.2. Dialogue

Considerations for accountability and shared understandings need to be discussed across practitioners, universities and professional associations, as highlighted by Hill and Miles (2012) and Reed and Fereday (2016). Key areas for this dialogue needs to include:

(1) what are the links and relationships between HADE and all engineering. This will need to examine the current discourse in the humanitarian and development sectors as well as the contemporary role of engineers.
(2) how can impact and outcomes been measured and evaluated. This will need to consider all aspects of educational offerings for university staff and students as well as external partners, individuals, communities and funding bodies. However, this can build from existing literature such as that on SL.
(3) what preparation is required for external projects and opportunities, in terms of students but also university staff and supervisors and external partners and communities.
(4) what approaches to external engagement are appropriate and how can best practice from the humanitarian and development sectors be incorporated and followed, including ethical frameworks and requirements from engineering and beyond.
(5) how can student learning and outcomes be recognised to support both future learning, employability and mobility across countries, in line with existing engineering accords.

To support dialogue in Australasia, a cross-institutional network of universities working the area has been established (Humanitarian Engineering Network of Australasia) which includes EWB-

Australia and other aid and development organisations, and a dedicated position paper on humanitarian engineering (the term used in Oceania) developed in conjunction with ACED,. This highlights four priorities for further development and support, including the need for shared understanding to underpin growth fostered by a national advisory group, and support and recognition for academics (ACED 2018). At the time of writing, discussions were underway for a potential dedicated Community of Practice for Humanitarian Engineering within Engineers Australia to foster and capture dialogue at a national level.

International groups and networks should be utilised to support discussions and share best practices. The *UNESCO UNITWIN Network in Humanitarian Engineering* is one example led globally by Coventry University while École polytechnique fédérale de Lausanne (EPFL) has hosted the *UNESCO Chair in Technologies for Development* since 2007. Many programmes have a link to national EWB organisations and the international network of EWB is another relevant group to support global discussions. A recent example is the Global Engineering Certificate developed with support from EWB-Canada. MOOCs and online courses provide opportunities for collaborations across countries and contributions to professional certificates or recognition. Agreements such as the Washington Accord, the Bologna Declaration or the EUR-ACE Accord could provide further mechanisms for discussion.

6.3. Limitations and further work

This study was based on accessible materials, it did not collect new primary data from those involved with designing or delivering HADE education. Further details here would provide greater depth of programme goals, curriculum design and delivery. A further synthesis study would be of value, utilising evaluations of individual HADE education programmes and initiatives, to draw out approaches and content, and their benefits.

7. Conclusion

The number of engineering programmes with a link to humanitarian action and development has increased dramatically since 2000 in support of development frameworks, new professional competencies and student interest. This has created a spectrum of programmes which have been integrated into degrees in various ways. However, the variety and differences in approaches means there is a need to ensure quality education and practice. Existing networks such as EWB and qualification frameworks such as the European Humanitarian Qualifications Framework could serve as a basis to ensure programmes are meeting the expectations of students and practitioner organisations without losing national identities and flexibility. Open and constructive dialogue is necessary starting with terminology and definitions, focusing on common themes or aims. This is required to support the positive impact engineers are having on the social issues, challenges and opportunities of our time. This could trigger a larger shift within engineering, ensuring the ideas of engineering efforts within humanitarian action and development are embedded as core within engineering, bringing an explicit focus on human well-being without the need for a separate focus.

Disclosure statement

The first two authors are both involved with the design and delivery of HADE education at their respective institutions and are past volunteers and employees of EWB-Australia. The second author is a core member of the UNESCO UNITWIN Network in Humanitarian Engineering, while the first author is a co-founder of the Humanitarian Engineering Network of Australasia.

Notes on contributors

Jeremy Smith is a Lecturer in the Research School of Electrical, Energy and Materials Engineering at the Australian National University. His current research is focused on humanitarian engineering education and practice in Australia.

He has designed and delivered university courses from first year through to specialised masters courses. Jeremy has a M.Phil in Engineering, a Graduate Certificate in Teaching and Learning in Higher Education, is a Senior Fellow of the Higher Education Academy (SFHEA) and received a national Award for Teaching Excellence at the 2017 Australian Awards for Teaching Excellence.

Dr Anh Tran is a Senior Lecturer in Humanitarian Engineering at the Faculty of Engineering, Environments and Computing, which she joined in 2015. She is also the head of research for the UNESCO UNITWIN Network of Humanitarian Engineering, in which Coventry University is the global lead institution. Prior to this post, she worked at Flinders University and the University of South Australia as a lecturer and research assistant. She received a BEng (Honours) and a Ph.D degree in Chemical Engineering from the University of Queensland. She also has more than 10 years' experience in international development work in South-east Asia, South Asia, South America and Africa and remote Indigenous Australian communities.

Prof Paul Compston is a researcher in the composite materials groups at the Research School of Electrical, Energy and Materials Engineering at the Australian National University. Paul has a background in materials and manufacturing research and is currently the Deputy Director, Australian Research Council (ARC) Training Centre for Automated Manufacture of Advanced Composites. His education roles have included Associate Director of Undergraduate Education in Research School of Engineering, Associate Dean (Education) for the ANU College of Engineering and Computer Science (CECS), and acting PVC (Student Experience) at the ANU.

ORCID

Jeremy Smith http://orcid.org/0000-0002-3991-4059

References

Aardema, B. L., and C. C. Muguruza. 2014. "The Humanitarian Action Qualifications Framework: A Quality Assurance Tool for the Humanitarian Sector." *Tuning Journal for Higher Education* 1 (2): 429–462.

ABET. 2015. *Criteria for Accrediting Engineering Programs*. Baltimore, MD: Engineering Accreditation Commission.

ACED. 2018. *Humanitarian Engineering Education Providing an opportunity for a New Generation of Engineers*. Position Statement April 2018, Australian Council of Engineering Deans.

Allenby, B., C. F. Murphy, D. Allen, and C. Davidson. 2009. "Sustainable Engineering Education in the United States." *Sustainability Science* 4 (1): 7–15.

Amadei, B., R. Sandekian, and E. Thomas. 2009. "A Model for Sustainable Humanitarian Engineering Projects." *Sustainability* 1 (4): 1087–1105.

Amadei, B., and W. A. Wallace. 2009. "Engineering for Humanitarian Development." *IEEE Technology and Society Magazine* 28 (4): 6–15.

Baaoum, M. 2018. "Humanizing Engineering Education: A Comprehensive Model for Fostering Humanitarian Engineering Education." *International Journal of Modern Education Studies* 2 (1): 1–23.

Berg, D. R., T. Lee, and E. A. Buchana. 2016. "A Methodology for Exploring, Documenting, and Improving Humanitarian Service Learning in the University." *Journal of Humanitarian Engineering* 4 (1): 1–7.

Bielefeldt, A. R., and N. Canney. 2014. "Impacts of Service-Learning on the Professional Social Responsibility Attitudes of Engineering Students." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* 9 (2): 47–63.

Bielefeldt, A. R., N. Canney, C. Swan, and D. W. Knight. 2016. "Contributions of Learning through Service to the Ethics Education of Engineering Students." *International Journal for Service Learning in Engineering* 11 (2): 1–17.

Bielefeldt, A., K. Paterson, and C. Swan. 2009. *Measuring the Impacts of Project-Based Service Learning*. Austin, TX: American Society for Engineering Education.

Bielefeldt, A., K. Paterson, C. Swan, O. Pierrakos, D. O. Kazmer, and A. Soisson. 2013. "Spectra of Learning Through Service Programs." Presented at the 120th ASEE Annual Conference and Exposition, Atlanta.

Bixler, G., J. Campbell, R. Dzwonczyk, H. L. Greene, J. Merrill, and K. M. Passino. 2014. "Humanitarian Engineering at The Ohio State University: Lessons Learned in Enriching Education While Helping People." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* Fall: 78–96.

Boni, A., and A. Pérez-Foguet. 2008. "Introducing Development Education in Technical Universities: Successful Experiences in Spain." *European Journal of Engineering Education* 33 (3): 343–354.

Bourn, D., and I. Neal. 2008. *The Global Engineer: Incorporating Global Skills within UK Higher Education of Engineers*. London: Engineers Against Poverty.

Bratton, M. 2014. "Global TIES: Ten Years of Engineering for Humanity." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* Fall: 205–221.

Bucks, G. W., K. A. Ossman, T. J. Bailey, L. A. Folger, R. Schwind, G. A. Notorgiacomo, and J. D. Wells. 2015. "Engineering Your Community: Experiences of Students in a Service-Learning Engineering Design Course." Presented at the 122nd ASEE Annual Conference and Exposition, Seattle, WA, June 14–17, 2015.

Campbell, R. 2013. "How Can Engineering Students Learn to Care? How Can Engineering Faculty Teach to Care?" In *Engineering Education for Social Justice: Critical Explorations and Opportunities*, edited by J. Lucena, 111–131. Dordrecht: Springer+Business Media. Philosophy of Engineering and Technology 10.

Campbell, R., and D. Wilson. 2011. *The Unique Value of Humanitarian Engineering*. Vancouver, BC: American Society for Engineering Education.

Cañavate, J., and J. Casasus. 2010. "Humanitarian Engineering in Spain: Ingenieros sin Fronteras." *IEEE Technology and Society Magazine* 29 (1): 12–19.

Catalano, G. D. 2006. *Engineering Ethics: Peace, Justice, and the Earth*. London: Synthesis Lectures on Engineers, Technology, and Society, Morgan & Claypool.

Chisolm, R., E. T. Gall, L. Read, and F. R. Salas. 2014. "Lessons from a Student-led Development Project in Peru: Aligning Technical and *Educational Perspectives*." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* Fall (Special Edition): 525–539.

CODEV. n.d. *MOOC: Science and Technology for DRR*. Accessed February 1, 2017. http://cooperation.epfl.ch/Education/DRR-MOOC.

Colledge, T. H. 2014. "Engineering and Engaged Scholarship at Penn State Part II: The Existing Ecosystem." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* Fall (Special Edition): 114–147.

Conlon, E. 2008. "The New Engineer: Between Employability and Social Responsibility." *European Journal of Engineering Education* 33 (2): 151–159.

Cuny, F. 1983. *Disasters and Development*. New York, NY: Oxford University Press.

Dale, A. T., E. R. Lennox, R. E. Best, D. McKahn, J. L. Hess, and M. K. Jensen. 2014. "Connections Without Command: ESW's Service Learning Approach." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* Fall (Special Edition): 48–61.

Davis, R. E., S. Krishnan, T. L. Nilsson, and P. F. Rimland. 2014. "IDEAS: Interdisciplinary Design Engineering and Service." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* Fall (Special Edition): 165–179.

Davis, K., and R. Lambert. 2002. *Engineering in Emergencies: A Practical Guide for Relief Workers*. 2nd ed. London: ITDG.

Dean, J. H., and D. L. Van Bossuyt. 2014. "Breaking the Tyranny of the Semester: A Phase-Gate Sprint Approach to Teaching Colorado School of Mines Students Important Engineering Concepts, Delivering Useful Solutions to Communities, and Working on Long Time Scale Projects." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* Fall (Special Edition): 222–239.

Dika, S. L., B. Tempest, and M. A. Pando. 2013. "Creating Socially Aware Engineers Through International Service Learning." Presented at the ASEE Annual Conference.

Dowling, D., and R. Hadgraft. 2012. "What Should We Teach? Defining Your Discipline to Drive Curriculum Renewal: an Environmental Engineering Case Study." Presented at the SEFI 40th annual conference, Thessaloniki, Greece, September 23–26, 2012.

Duff, F. E., L. J. Marshall, L. W. Hauser, H. W. Ausland, T. J. Houser, B. Kusi, and C. L. Just. 2014. "The International Engineering Service Program at the University of Iowa." *International Journal for Service Learning in Engineering* Fall (Special Edition): 300–333.

Duffy, J., L. Barrington, C. West, M. Heredia, and C. Barry. 2011. "Service-learning Integrated throughout a College of Engineering (SLICE)." *Advances in Engineering Education* 2 (4): 1–23.

Dzombak, R., and J. Kramer. 2017. *Development Engineering: A Critical Overview*. Berkeley, CA: Blum Center for Emerging Economies at UC Berkeley.

Dzombak, R., and K. Mehta. 2013. "Scholarly Advances in Humanitarian Engineering and Social Entrepreneurship: A Typology of Research Publications." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* Fall (Special Edition): 98–116.

Dzombak, R., S. Mouakkad, and K. Mehta. 2016. "Motivations of Women Participating in a Technology-Based Social Entrepreneurship Program." *Advances in Engineering Education* 5 (1): n1.

EA. 2011. *Stage 1 Competency Standard for Professional Engineer*. Canberra: Engineers Australia.

Engineers Canada. 2016. *2016 Accreditation Criteria and Procedures*. Ottawa, ON: Canadian Engineering Accreditation Board.

Ermilio, J., G. Clayton, and M. Kabalan. 2014. "Villanova Engineering Service Learning." *International Journal for Service Learning in Engineering* Fall (Special Edition): 334–353.

ESW. 2018. *Chapters*. Accessed February 12, 2019. https://www.eswglobal.org/chapters.

EWB-USA. 2019. Find a Chapter. Accessed February 12, 2019. https://www.ewb-usa.org/find-a-chapter/.

FEANI. 2016. *Welcome to FEANI*. Accessed June 8, 2018. https://www.feani.org/.

Fenner, R. A., C. M. Ainger, H. J. Cruickshank, and P. M. Guthrie. 2005. "Embedding Sustainable Development at Cambridge University Engineering Department." *International Journal of Sustainability in Higher Education* 6 (3): 229–241.

Ferrer-Martí, L., M. Garfí, and I. Ferrer. 2015. "Cooperation and Human Development Projects as Bachelor, Master and PhD Thesis: Evaluating an Internship Program." *Procedia – Social and Behavioral Sciences* 196: 63–68.

Fiksel, J. 2006. "Sustainability and Resilience: Toward a Systems Approach." *Sustainability: Science, Practice and Policy* 2 (2): 14–21.

Flower, I. 2016. "The Work of Engineers for Overseas Development in Humanitarian Aid." *Proceedings of the Institution of Civil Engineers – Civil Engineering* 169 (5): 41–48.
Foster, K. 2010. "Telehealth in Sub-Saharan Africa: Lessons for Humanitarian Engineering." *IEEE Technology and Society Magazine* 29 (1): 42–49.
GDEE. 2015. *Global Engineering: Key Professionals for Sustainable Human Development*. Barcelona: Global Dimension in Engineering Education.
Gilbert, D. J., M. Lehman Held, J. L. Ellzey, W. T. Bailey, and L. B. Young. 2015. "Teaching 'Community Engagement' in Engineering Education for International Development: Integration of an Interdisciplinary Social Work Curriculum." *European Journal of Engineering Education* 40 (3): 256–266.
Glade, S., C. Karter, and K. Pagilla. 2014. "Case Studies from a Community-Focused Engineering Program with Projects in Haiti and Nicaragua." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* Fall (Special Edition): 551–562.
Global Association. n.d. *Global MDP Program*. Accessed June 2, 2018. http://mdpglobal.org/global-mdp-program/.
Greet, N. 2014. "Building a Humanitarian Engineering Network–A Collaborative Challenge." Humanitarian innovation Conference, 19–20.
Harsh, M., M. J. Bernstein, J. Wetmore, S. Cozzens, T. Woodson, and R. Castillo. 2017. "Preparing Engineers for the Challenges of Community Engagement." *European Journal of Engineering Education* 42 (6): 1154–1173.
Hill, S., and L Miles. 2012. "What Do Students Understand by the Term 'Humanitarian Engineering'." In *Innovation, Practice and Research in Engineering Education*, 1–11. Coventry: Coventry University.
Holmberg, J., M. Svanström, D.-J. Peet, K. Mulder, D. Ferrer-Balas, and J. Segalàs. 2008. "Embedding Sustainability in Higher Education through Interaction with Lecturers: Case Studies from Three European Technical Universities." *European Journal of Engineering Education* 33 (3): 271–282.
Huntzinger, D. N., M. J. Hutchins, J. S. Gierke, and J. W. Sutherland. 2007. "Enabling Sustainable Thinking in Undergraduate Engineering Education." *International Journal of Engineering Education* 23 (2): 218–230.
ICE. 2017. *ICE Member Attributes*, Institution of Civil Engineers. Accessed March 26, 2017. https://www.ice.org.uk/my-ice/membership-documents/member-attributes.
ISF. 2016. Accessed April 2, 2017. https://formacion.isf.es/.
Jesiek, B. K., Q. Zhu, S. E. Woo, J. Thompson, and A. Mazzurco. 2014. "Global Engineering Competency in Context: Situations and Behaviors." *Online Journal for Global Engineering Education* 8 (1): 1.
Jordaan, M. 2014. "Community-based Project Module: A Service-learning Module for the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria." *International Journal for Service Learning in Engineering* Fall (Special Edition): 269–282.
Kinsner, W. 2014. "Humanitarian Engineering Education: Examples." Proc. 2014 Canadian Engineering Education Association (CEEA14) Conference. Canmore, AB, Canada.
Lam, J. W., F. J. Mah, P. B. Miller, and A. Meikleham. 2016. "Developing Role Models for Engineering and Sustainable Development: Engineers without Borders' Global Engineering Certificate." In *New Developments in* Engineering Education for Sustainable Development, edited by W. L. Filho and S. Nesbit, 139–149. Cham: Springer.
Lewis, R. S. 2014. "Insights from a Global Engineering Outreach Course." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* Fall (Special Edition): 256–268.
Leydens, J. A., and J. C. Lucena. 2014. "Social Justice: A Missing, Unelaborated Dimension in Humanitarian Engineering and Learning Through Service." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* 9 (2): 1–28.
Lima, M. 2014. "The LSU Community Playground Project: Reflections on 16 Years of an Engineering Service-Learning Program." *International Journal for Service Learning in Engineering* Fall (Special Edition): 492–508.
Litchfield, K., and A. Javernick-Will. 2014. "Investigating Gains from EWB-USA Involvement." *Journal of Professional Issues in Engineering Education and Practice* 140 (1): 04013008.
Litchfield, K., and A. Javernick-Will. 2015. ""I am an Engineer AND": A Mixed Methods Study of Socially Engaged Engineers." *Journal of Engineering Education and Practice* 104 (4): 393–416.
Lohmann, J. R., H. A. Rollins, and J. Joseph Hoey. 2006. "Defining, Developing and Assessing Global Competence in Engineers." *European Journal of Engineering Education* 31 (1): 119–131.
Lucena, J., G. Downey, B. Jesiek, and S. Elber. 2008. "Competencies Beyond Countries: The Re-Organization of Engineering Education in the United States, Europe, and Latin America." *Journal of Engineering Education* 97 (4): 433–447.
Male, S. A., M. B. Bush, and E. S. Chapman. 2010. "Perceptions of Competency Deficiencies in Engineering Graduates." *Australasian Journal of Engineering Education* 16 (1): 55–68.
Malkin, R., and L. J. Calman. 2014. "Service-Learning in Biomedical Engineering: Engineering World Health (EWH)." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* Fall (Special Edition): 39–47.
Mathie, A., and G. Cunningham. 2003. "From Clients to Citizens: Asset-Based Community Development as a Strategy for Community-Driven Development." *Development in Practice* 13 (5): 474–486.
Mazzurco, A., and B. K. Jesiek. 2014. "Learning from Failure: Developing a Typology to Enhance Global Service-Learning Engineering Projects." 121st ASEE Annual Conference and Exposition, Indianapolis, Indiana, June 15–18, 2014.

Mazzurco, A., and B. K. Jesiek. 2017. "Five Guiding Principles to Enhance Community Participation in Humanitarian Engineering Projects." *Journal of Humanitarian Engineering* 5 (2): 1–9.
Meganck, M. 2010. "From Boy Scouts and Missionaries, to Development Partners." *IEEE Technology and Society Magazine* 29 (1): 27–34.
Moskal, B. M., and J. Gosink. 2007. "Humanitarian Engineering Curriculum: Defining Student Learning Outcomes." Presented at the ASEE 2007.
Moskal, B. M., C. K. Skokan, D. R. Muñoz, and J. Gosink. 2008. "Humanitarian Engineering: Global Impacts and Sustainability of a Curricular Effort." *International Journal of Engineering Education* 24 (1): 162–174.
Muñoz, D. R., and C. K. Skokan. 2007. "Humanitarian Engineering Programme: Conceptual Challenges." *World Transactions on Engineering and Technology Education* 6 (2): 253.
Nassar, A. R., K. Holmes, and K. Mehta. 2016. "Student Outcomes of Short-Term International Humanitarian Engineering Fieldwork." Frontiers in education Conference (FIE), 2016 IEEE, 1–9. IEEE.
Naughton, C. C., N. D. Manser, C. Prouty, K. Orner, M. E. Verbyla, M. A. Trotz, and J. R. Mihelcic. 2015. "Improving the Global Competency of Engineers Through the Peace Corps Master's International Program." 2015 ASEE southeast section conference.
Nieusma, D., and D. Riley. 2010. "Designs on Development: Engineering, Globalization, and Social Justice." *Engineering Studies* 2 (1): 29–59.
Oakes, W. C., C. B. Zoltowski, K. Schmotzer, and Ana Paula Valenca. 2015. "Integration of Curricular and Extra-Curricular Learning through Service." Presented at the 122nd ASEE Annual Conference and Exposition, Seattle.
OECD. 2017. *Humanitarian Development Coherence*. Paris: Development Co-operation Directorate, OCED.
ONGAWA. n.d. Accessed April 2, 2017. http://www.ongawa.org/who-we-are/.
Parkinson, A. 2007. "Engineering Study Abroad Programs: Formats, Challenges, Best Practices." *Online Journal for Global Engineering Education* 2 (2): 2.
Parsons, L. B. 1996. "Engineering in Context: Engineering in Developing Countries." *Journal of Professional Issues in Engineering Education and Practice* 122 (4): 170–176.
Passino, K. M. 2009. "Educating the Humanitarian Engineer." *Science and Engineering Ethics* 15 (4): 577–600.
Paye, S. 2010. "Ingénieurs Sans Frontières in France: From Humanitarian Ideals to Engineering Ethics." *IEEE Technology and Society Magazine* 29 (1): 20–26.
Pérez-Foguet, A., S. Oliete-Josa, and A. Saz-Carranza. 2005. "Development Education and Engineering: A Framework for Incorporating Reality of Developing Countries Into Engineering Studies." *International Journal of Sustainability in Higher Education* 6 (3): 278–303.
Pinnell, M., M. Daniels, K. Hallinan, and G. Berkemeier. 2014. "Leveraging Students' Passion and Creativity: ETHOS at the University of Dayton." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* Fall (Special Edition): 180–190.
Purdue. 2019. EPICS Consortium Institutions. Accessed Februar 12, 2019. https://engineering.purdue.edu/EPICS/university/institutions.
Reed, B., and E. Fereday. 2016. "Developing Professional Competencies for Humanitarian Engineers." *Proceedings of the Institution of Civil Engineers – Civil Engineering* 169 (5): 49–56.
Roth, B., and C. Nelson. 2014. "Development of the Global Humanitarian Engineering Emphasis at Walla Walla University." *International Journal for Service Learning in Engineering* Fall (Special Edition): 354–366.
Sacco, D., and J. Knight. 2014. "TACs, ARCs and Project Process at EWB-USA." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* Fall (Special Edition): 33–38.
Schneider, J., J. A. Leydens, and J. Lucena. 2008. "Where is 'Community'?: Engineering Education and Sustainable Community Development." *European Journal of Engineering Education* 33 (3): 307–319.
Siniwski, M., S. G. Luca, J. S. Pal, and J. A. Saez. 2015. "Impacts of Service-Learning Projects on the Technical and Professional Engineering Confidence of First Year Engineering Students." Presented at the 122nd ASEE Annual Conference and Exposition, Seattle, WA, June 14–17, 2015.
Smith, J., B. Anderson, N. Brown, A. Colley, A. Stoakley, and J. Turner. 2017. "The Rise of Humanitarian Engineering Education in Australasia." 28th Annual conference of the Australasian association for engineering education (AAEE1017) order of Proceedings, Manly 2017.
Smith, J., P. Compston, S. Male, C. Baillie, and J. Turner. 2016. "Intensive Mode Teaching of a Humanitarian Engineering Course to Enhance Service-Learning." *International Journal for Service Learning in Engineering* 11 (2): 38–54.
Sphere. n.d. The Sphere Project. Accessed May 8, 2018. http://www.sphereproject.org/about/.
Suhr, N., T. Griswold, R. Heighes, N. Hill, R. Hill, W. Parker, K. Sommers, J. Suhr, and F. Fiedler. 2014. "Institutional Hurdles to Student Humanitarian Groups: Lessons Learned from a Failed Project." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* Fall (Special Edition): 540–550.
Tayler, Y. 2016. Humanitarian Engineering: Innovative Approaches and Partnerships in Crisis Response, *MENA Knowledge and Learning Quick Notes Series*, 157, June.
Thomas, J., P. Matous, P. Café, and A. El-Zein. 2017. "Lessons Learned from the Design and Delivery of a New Major in Humanitarian Engineering." 28th Annual Conference of the Australasian association for engineering education (AAEE1017) order of Proceedings, Manly 2017.

Tucker, B. G., D. O. Kazmer, A. R. Bielefeldt, K. Paterson, O. Pierrakos, A. Soisson, and C. Swan. 2013. "Principles of Sustaining Partnerships between Higher Education and their Larger Communities: Perspectives from Engineering Faculty Engaged in Learning Through Service." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* Fall (Special Edition): 48–63.

Turner, J., N. Brown, and J. Smith. 2015. "Humanitarian Engineering: What Does It All Mean?" 26th Annual Conference of the Australasian association for engineering education (AAEE1015) order of Proceedings.

UNDP. 2014. *Sustaining Human Progress: Reducing Vulnerabilities and Building Resilience*. New York, NY: United Nations Development Programme.

UNDP. 2015. *Work for Human Development*. New York, NY: United Nations Development Programme.

VanderSteen, J. D. J. 2008. *Humanitarian Engineering in the Engineering Curriculum* (Doctor of Philosophy). Queens, Kingston, Ontario, Canada.

Vandersteen, J. D. J., C. Baillie, and K. Hall. 2009. "International Humanitarian Engineering." *IEEE Technology and Society Magazine* 28 (4): 32–41.

VanderSteen, J. D. J., K. R. Hall, and C. Baillie. 2010. "Humanitarian Engineering Placements in our own Communities." *European Journal of Engineering Education* 35 (2): 215–223.

Walther, J., S. E. Miller, and N. W. Sockacka. 2017. "A Model of Empathy in Engineering as a Core Skill, Practice Orientation, and Professional Way of Being." *Journal of Engineering Education* 106 (1): 123–148.

WEFO. 2015. *WEFO Engineers for a Sustainable Post 2015*. Paris: World Federation of Engineering Organizations.

Zoltowski, C. B., and W. C. Oakes. 2014. "Learning by Doing: Reflections of the EPICS Program." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* Fall (Special Edition): 1–32.

Appendix

Table A1. Programmes included for data analysis, $N = 67$, including published source where identified.

Africa	
Programme	Institution
Community Project Module (Jordaan 2014)	University of Pretoria
Asia (Excluding Oceania)	
Programme	Institution
Global Scientists and Engineers Programme (GSEP)	Tokyo Institute of Technology
Masters in Technology and Development	Indian Institute of Technology Bombay
Earthquake Engineering Programme	Tokyo Institute of Technology
MSEngg Programmes	Yargon Technology University
Global Engineering for Development, Environment and Society Graduate Major	Tokyo Institute of Technology
Bachelor of Science in Physics Renewable Energy Major	Royal University of Phnom Penh
Technology Development Supervised Learning	Indian Institute of Technology Bombay
Canada	
Programme	Institution
Certificate in Global Engineering	University of Toronto
Global Engineering Certificate	Memorial University of Newfoundland
Global Engineering Certificate	University of Calgary
Global Engineering Certificate (Lam et al. 2016)	EWB Canada
Europe (excluding UK)	
Programme	Institution
International Entrepreneurship and Development minor	Delft University of Technology
Disaster and Recovery Minor	Wageningen University
Technology in Sustainable Development (TiSD) annotation	Delft University of Technology
Technology and Development Track	Wageningen University
Cooperation and Development Center CoDev	École Polytechnique Federale De Lausanne
Oceania	
Programme	Institution
Master of Emergency and Disaster Management (MEMDM)	Charles Darwin University
Master of Integrated Water Management	University of Queensland
Humanitarian Engineering Major (Thomas et al. 2017)	University of Sydney
Diploma in Global Humanitarian Engineering (Smith et al. 2017)	University of Canterbury
Minor in Humanitarian Engineering	University of Adelaide

(*Continued*)

Table A1. Continued.

Africa	
Programme	Institution
Minor in Humanitarian Engineering (Smith et al. 2017)	Australian National University
UK	
Programme	Institution
Humanitarian Engineering and Computing Add + vantage (Hill and Miles 2012)	Coventry University
Global Humanitarian Engineering MSc	Coventry University
Infrastructure in Emergencies MSc	Loughborough University
MPhil in Engineering for Sustainable Development (Fenner et al. 2005)	University of Cambridge
MSc Engineering for International Development	University College London
MSc Earthquake Engineering with Disaster Management	University College London
USA	
Programme	Institution
Master of Science Professional track degree programme in Civil Engineering with an emphasis in Engineering for Developing Communities (Amadei and Wallace 2009; Amadei, Sandekian, and Thomas 2009)	University of Colorado Boulder
Engineering (Humanitarian Engineering), BSE	Arizona State University
GlobalResolve	Arizona State University
Humanitarian Engineering Minor (Passino 2009; Bixler et al. 2014)	Ohio State Uni
Minor in Humanitarian Engineering and Science	Missouri University of Science and Technology
Humanitarian Engineering Minor	Oregon State University
Certificate in Engineering and Community Engagement (Dzombak and Mehta 2013; Dzombak, Mouakkad, and Mehta 2016; Nassar, Holmes, and Mehta 2016)	Penn State University
Entrepreneurship and Innovation Minor with Social Entrepreneurship Cluster (Dzombak and Mehta 2013; Dzombak, Mouakkad, and Mehta 2016; Nassar, Holmes, and Mehta 2016)	Penn State University
Humanitarian Engineering Minor (Moskal and Gosink 2007; Muñoz and Skokan 2007; Leydens and Lucena 2014; Dean and Van Bossuyt 2014)	Colorado School of Mines
Area of Special Interest in HE (Moskal and Gosink 2007; Muñoz and Skokan 2007; Leydens and Lucena 2014; Dean and Van Bossuyt 2014)	Colorado School of Mines
Humanitarian Engineering Concentration	Baylor
Global Humanitarian Engineering Emphasis (Roth and Nelson 2014)	Walla Walla University
Graduate Concentration in Engineering for International Development (in Civil and Environmental Engineering) (Naughton et al. 2015)	University of South Florida
Minor in Global Engineering (Amadei and Wallace 2009 Amadei, Sandekian, and Thomas 2009;)	University of Colorado Boulder
Certificate in Global Engineering (Amadei and Wallace 2009 Amadei, Sandekian, and Thomas 2009;)	University of Colorado Boulder
Graduate Certificate in Engineering for Developing Communities (Amadei and Wallace 2009; Amadei, Sandekian, and Thomas 2009)	University of Colorado Boulder
MIT Entrepreneurship and Innovation Minor	MIT
Global Development Track	MIT
Minor in Engineering for Sustainable Development	Johns Hopkins University
Global Development Engineering Certificate	Duke University
Global Health Major or Minor (Malkin and Calman 2014)	Duke University
International Sustainable Development Engineering (ISDE) Certificate (Paterson and Fuchs)	Michigan Technological University
GO ENGR	Ohio State Uni
Designated Emphasis in Development Engineering (Dzombak and Kramer 2017)	UC Berkeley
Community- Based Learning	Santa Clara University
Graduate Certificate in Frugal Innovation	Santa Clara University
Global TIES (Bratton 2014)	University of California San Diego
SLICE (Duffy et al. 2011)	University of Massachusetts Lowell
GEO (Lewis 2014)	Brigham Young University
Community Playground Project (Lima 2014)	Louisiana State University
UI-IESP (Duff et al. 2014)	University of Iowa
EPICS@ Purdue (Oakes et al. 2015; Zoltowski and Oakes 2014)	Purdue University
Engineering Major (Davis et al. 2014)	Santa Clara University
Dartmouth Humanitarian Engineering	Dartmouth College
VESL (Ermilio, Clayton, and Kabalan 2014)	Villanova University
Hunt Institute for Engineering and Humanity	Southern Methodist University
Sustainable Engineering and Development Scholars (SEADS) Programme	Princeton University
ETHOS (Engineers in Technical Humanitarian Opportunities of Service-Learning) (Pinnell et al. 2014)	University of Dayton

Chapter 3: Design for Dissemination - Development of a Humanitarian Engineering Course for Curriculum Sharing

Foreword

Following the previous Chapter describing Humanitarian Engineering Education (HumEngEdu) internationally, its understandings and delivery, this Chapter is the first of three which outlines the design, development and delivery of the Engineering for a Humanitarian Context (EfaHC) course at the ANU. A dedicated course was identified as a key requirement of the envisioned HumEngEdu pathway, filling a perceived gap in students' programs between the introductory EWB Challenge in first year and larger engagements such as final-year group or individual research or development projects. This was seen at both the ANU, through the experience of supervisors of final-year projects, and as well as nationally by EWB-A. In response, EWB-A developed the EWB Humanitarian Design Summits to target middle year students, to be delivered as intensive 2-week study aboard program.

This Chapter addresses the first research question on curriculum approaches for HumEngEdu, and incorporates lessons from the first Chapter. It outlines the curriculum approach and final design of the course. The course was developed in conjunction with EWB-A, who are subject matter experts and a key practitioner organisation. As a dedicated later year engineering elective, EfaHC is believed to have been the first course of its type in Australia. As such, a course development approach was adopted to allow the course, its topics, delivery and content, to be available and utilised by other institutions. A development approach that would allow the course to be delivered in different modes was required, so that the course could be delivered in either a traditional semester session or utilising an intensive mode teaching approach. The need for the latter was identified from early research as necessary for two reasons: first, to help build a learning community around the course and its content; and second, so that the course could include and accommodate short-term domestic or study-abroad experiences. This was done with the EWB Design Summits in mind, as these had only just commenced when the EfaHC course was being developed, but the potential was seen for these Summits to be incorporated into the course for credit. This influenced the decision to select an intensive teaching delivery mode for the course, to enable the inclusion of EWB Summits if deemed appropriate.

Findings and recommendations from research and articles identified for the previous Chapter were incorporated where relevant. This included dedicated introductory HumEng courses and short-term international experiences. Curriculum approaches, scaffolding and assessment from existing courses were considered along with key content topics. Content was considered from the perspective of the Australian humanitarian and development context, and course development incorporated review and input from Australian practitioners and experts.

While the paper focuses on the development and design of the course, some initial primary data is provided. This outlines the number of students enrolled in the course, the delivery mode they undertook (Canberra based only or incorporating the EWB Summit), and student feedback on the intensive teaching mode utilised.

Design for Dissemination - Development of a Humanitarian Engineering Course for Curriculum Sharing

Jeremy Smith[a], Jenny Turner[b] and Nick Brown[b]
Australian National University[a] and Engineers Without Borders Australia[b]

Structured Abstract

BACKGROUND OR CONTEXT

Humanitarian engineering education has received significant interest over the last 15 years at universities in the developed world. Numerous education initiatives and programs for humanitarian engineering and related areas including global engineering and engineering for development are available to students (such Amadei and Wallace, 2009; Campbell and Wilson, 2011, and Leydens and Lucena, 2014). These can involve a mix of traditional coursework along with a significantly levels of service-learning with students undertaking projects of various sizes and durations with community organisations on an identified need or challenge (VanderSteen et al, 2009). In Australia, service-learning projects are often incorporated into final year engineering projects, either group based or individual. These are supported by curriculum opportunities such as the EWB Challenge for first year students. However, across Australia there has been a significant gap in humanitarian engineering coursework for later year students to support service-learning opportunities.

PURPOSE OR GOAL

To bridge the gap between the EWB Challenge in first year and final year projects a dedicated 3rd/4th year Engineering for a Humanitarian Context course was developed and piloted. This was aimed at giving students greater understanding of humanitarian engineering practice and specific tools that can be applied to projects while at university or beyond. To promote the uptake of curriculum in this area across Australia the course and its material were designed to be made available to other universities interested in developing similar courses to support their students.

APPROACH

To ensure the course and its material could be shared with other universities interested in developing new courses a specific curriculum development process was utilised. This was based on a systems engineering vee model to provide a high level of traceability and adaptability for future delivery (Faulconbridge and Dowling, 2010). Starting with course learning outcomes the course was defined in finer detail to the level of outcomes for individual topics and classes. Specific teaching and learning activities were then selected to meet those outcomes, which combined to ‘produce’ the course as a whole. This approach allows individual elements of a course to be modified or adapted for delivery according to the strengths and opportunities available at different universities.

DISCUSSION

The course developed using the curriculum approach here was delivered in two different modes, one a five week intensive based delivery entirely in and around an Australian university, the other incorporating a two week in-country experience in the form of the EWB Humanitarian Design Summit in Cambodia. Feedback and lessons from both the content and delivery of the course in each mode, along with the ability to adapt the course based on the development process were captured and evaluated.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The course developed along with its materials are being made available to other universities interested in delivering similar courses. Due to the development approach, it is easier for those institutions to select specific elements of the course for their particular context.

Introduction

The field of humanitarian engineering education (HEE) has grown rapidly since it emerged in its current form around 2000. HEE focuses on the application of engineering for a broad range of humanitarian interventions, from disaster response through to addressing long-term disadvantage (Campbell and Wilson, 2011). Some understandings of humanitarian engineering focus on technology development for developing communities or countries (such as Amadei and Wallace, 2009; and Nilsson et al, 2014) while others incorporate broader outcomes including social justice (Leydens and Lucena, 2014) and ensuring due benefits are received by the communities involved (VanderSteen et al, 2009). HEE has been encouraged and supported by the emergence of organisations such as Engineers Without Borders in numerous countries, highlighting strong student interest, while recently the benefit of HEE in attracting more women into engineering has been identified (Hill and Miles, 2012; and Nilsson, 2015).

While many institutions in the USA, UK and Canada have some form of humanitarian engineering or related opportunities for students, a smaller number have formal qualifications available. In the USA, these are often a minor track such as those at Ohio State University, Penn State University and Colorado School of Mines while the University of Colorado Boulder offers a Graduate Certificate in Engineering for Development. In the UK, undergraduate programs are available at Coventry University and a newly approved bachelors at the University of Wales Trinity Saint David. A number of coursework Master of Science programs have recently been launched including Humanitarian Engineering and Computing at Coventry University (since 2013) and Engineering for International Development at University College London (since 2015).

In Australia, many of the HEE initiatives have been developed and supported by Engineers Without Borders Australia (EWB). These include the EWB Challenge, a design project for first year introductory courses, the Undergraduate Research Program, to provide projects for final year capstone courses, and the Humanitarian Design Summit, which provides facilitated two-week in-country experiences incorporating a mix of workshops and community visits. The initiatives are available for universities to be incorporated into their courses and programs. Other recent related initiatives within engineering education include the work on engineering and social justice at the University of Western Australia (O'Shea et al, 2012), Indigenous engineering at the University of Wollongong (Goldfinch et al, 2014) and engineering in emergencies at Charles Darwin University. At the Australian National University (ANU) the EWB initiatives have been combined with local service-learning style projects to create a semi-structured pathway for students to engage with humanitarian or community engineering projects at each of their year levels (Smith and Browne, 2014).

However there are a lack of dedicated humanitarian engineering courses in Australia, particularly when compared to the USA and UK. This may be related to the recent emergence of the field from both an education and practice perspective although the growth and interest in EWB's HEE initiatives highlight a demand and interest in the area. For example, since its launch in 2007 the EWB Challenge has expanded and is used in over 50 universities is Australia, NZ, the UK and Ireland.

A joint project was established between EWB and the ANU to develop a dedicated 3rd/4th year engineering elective focused on humanitarian engineering. In particular, the course was designed to fill a perceived gap between introductory experiences such as the EWB Challenge and later-year immersive or service-learning based projects such as those available through the Undergraduate Research Program. With no comparable courses in Australia, the aim was to develop a course that could be shared and disseminated with other institutions interested in HEE or used as a starting point for developing their own. The course would build on experiences from overseas offerings while incorporating elements of humanitarian engineering specific to Australia, its location in Asia and own domestic challenges. In this way, a key requirement of the course would be to make its structure, delivery and material available for ease of dissemination to other institutions. The selection of a curriculum development approach for the course became a key element to ensure accessibility to the course and its material.

Curriculum Development

Curriculum development can be considered one part of a broader course design process. A course design process includes all the elements from establishing the need and demand for a course, through identifying student characteristics, determining content, teaching methods and assessment, and course evaluation (Toohey, 1999, p21). Within course design a number of beliefs, philosophies, views and approaches can be considered and incorporated to influence the developed course. Five philosophical approaches to curriculum were identified by Toohey (1999), each with different views of knowledge, processes for learning, roles for teachers and students, and organisation of content. A summary or discussion of these are beyond the scope of the paper here. However, considering the goal of the course, to fill a gap between first year and later year immersive, often project-based, courses, a relatively traditional course design approach was adopted. This would not incorporate project- or problem-based learning (as described in Heywood, 2005) but rather focus on humanitarian engineering as a discipline. This did not limit specific education approaches such as active or cooperative learning (Felder and Brent, 2013) which are at a lower-level of course design.

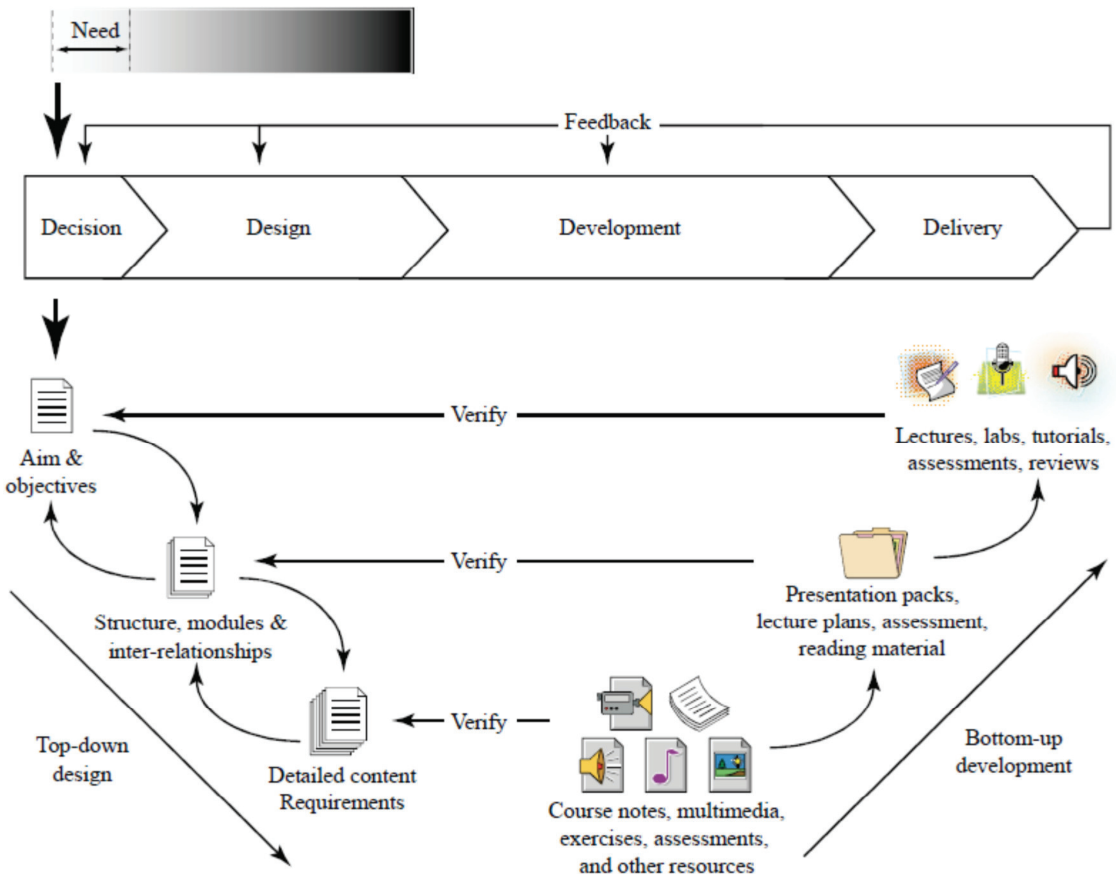


Figure 1: Curriculum development approach (from Faulconbridge and Dowling, 2010)

Within the approach selected there are numerous methods to determine and organise course content and material including Heywood, 2005; Ramsden, 2003; and Toohey, 1999. The project aim to ensure the curriculum structure and course material could be accessible and easy to disseminate was a key factor when considering the method to use. The method described by Faulconbridge and Dowling (2010), based on the systems engineering *vee* model (see Figure 1), was identified as an approach to support this aim.

For systems engineering the vee model consists of a top-down design phase followed by a bottom-up development phase, with verification taking place during the development activities (Blanchard and Fabrycky, 2010). At the top of the vee the highest level requirements for the system as a whole are defined. These are progressively detailed through sub-systems until the requirements each individual components are defined. The development phase then commences. Individual components are constructed and verified against their corresponding requirements. Development continues, packaging elements from lower levels into sub-systems, each of which are verified against the stated requirements. Finally the system as a whole is developed and verified against the system level requirements which started the process. This allows a very high-level of traceability through design and development. It also enables a certainly level of flexibility in development as potentially multiple different elements can be implemented to meet the requirements.

For curriculum, once the characteristics for an 'average' student are identified and the decision to develop a new course made, the design cycle commences (see Figure 1). This starts with course aims, objectives and learning outcomes. The structure and topics for the course are determined along with inter-relationships. Finally detailed content requirements for individual topics are documented. The curriculum development phase then starts. At the lowest level, individual learning activities are constructed which could consist of a reading, resource, or part or all of a tutorial, lecture or workshop. These are packaged into an appropriate *pack* which could be a lesson plan or a week-by-week semester schedule. Finally, the course as a whole is completed including assessment items and evaluation material. At each stage of the development process, material developed is verified against the requirements detailed, which at the highest level can utilise constructive alignment to ensure material, course learning outcomes and assessment are all in agreement.

This approach provides a high level of structure for the course which makes it potentially easier to disseminate, as well as providing adaptability and flexibility. Individual learning activities can be modified or changed and the course verified again. This gives the potential for activities such as case studies, guests or site visits to be tailored for a specific delivery of the course based on an institutions' strengths and available resources. As the curriculum approach is based on an engineering process, it is potentially easier for a course coordinator with an engineering background but no formal education training to follow as it can be explained in engineering terms. The application of the this curriculum development approach for a new humanitarian engineering course is outlined in the next section.

Course Design and Development

Initial requirements for the new course were established including pre-requisites (2 years minimum of engineering study), delivery time and mode, and a course description and learning outcomes. The latter incorporated review and comments from external experts and practitioners, to ensure the highest level requirements were representative of the humanitarian engineering sector in Australia. Following Figure 1, a collection of detailed topics was developed incorporating feedback and preparatory research. Seventeen topics were identified grouped into four areas as shown in Table 1. These were then decomposed into a total of 70 individual topics, each with its own learning outcome. This specified the depth and level of learning required, based on the SOLO Taxonomy (Heywood, 2005). Precedence of topics was determined as well as relationships. These represented the detailed content requirements at the bottom of the design phase.

Table 1: Course topics and delivery mechanisms

Topic		Canberra Delivery	Summit Delivery
1	**Humanitarian Contexts (Background History)**		
1.1	Types of humanitarian contexts, responses and interventions	Wk 1 Day 1	Initial w/shop, Phases 1, 4
1.2	History and overview of Australian domestic aid and development sector	Wk 1 Day 4	Initial w/shop
1.3	Overview of community development in Indo-Pacific (SE-Asia and Pacific)	Wk 1 Day 4	Initial w/shop, Phase 1
2	**Humanitarian Approaches and Models**		
2.1	Development and humanitarian response models	Wk 2 Day 1, Wk 2 Day 2, Wk 3 Day 1, Wk 4 Day 1	Return w/shop, Phases 1, 4
2.2	Development approaches and tools	Wk 2 Day 1, Wk 3 Day 1, Wk 4 Day 1	Phase 1
3	**Personal Practice**		
3.1	Communication skills	Wk 1 Day 3	Phases 1, 2
3.2	Cross-cultural awareness	Wk 1 Day 3	Phases 1, 2, 3
3.3	Working in a challenging environment	Wk 2 Day 3	Phases 1, 4
3.4	Critical analysis and reflection	Wk 1 Day 2	Initial w/shop, Phase 4
3.5	Ethical practice	Wk 1 Day 1, Wk 3 Day 3, Wk 4 Day 2	Return w/shop, Phase 1
4	**Engineering Practice**		
4.1	Engineering design and approaches	Wk 2 Day 1, Wk 3 Day 1, Wk 4 Days 1/2	Phases 1, 2
4.2	Evaluation and assessment of social, economic and environmental impacts	Wk 3 Day 3, Wk 3 Day 4, Wk 4 Day 1	Return w/shop, Phases 2, 4
4.3	Risk management and assessment	Wk 2 Day 3	Resources
4.4	Design standards and best practice	Wk 2 Day 2	Phase 2
4.5	Traditional knowledge	Wk 1 Day 2, Week 3 Day 2, Wk 4 Day 1	Resources / return w/shop
4.6	Appropriate technology	Wk 1 Day 2, Wk 2 Day 2, Wk 3 Days 1/2, Wk 4 Day 1	Phases 1, 2, 4
4.7	Technology transfer and diffusion	Wk 3 Day 4	Return w/shop, Phases 1, 2, 4

The development phase started by identifying and constructing learning activities, resources and material for each of the 70 topics, which were then verified against the learning outcomes for the corresponding topic. These were packaged according to the day of delivery during the course. Finally assessment items were developed. Constructive alignment was then used to ensure the assessment tasks and overall material met the course learning outcomes.

Course Delivery and Adaption

At the start of the design phase it was decided to offer the course in a five week intensive mode during the winter term. This allowed for a greater range of activities including longer practical activities and site visits. With the development of the EWB Humanitarian Design Summits the opportunity arose to incorporate these into the delivery of course as a Summit to Cambodia was running at the same time as the course. This allowed the course to be delivered in two parallel modes:

1. based entirely at ANU in Canberra
2. incorporating the overseas Design Summit with additional workshops at ANU

The enrolments for the course and each of the delivery modes is show in Table 2. These parallel delivery modes allowed the course structure developed to be tested as learning activities for the two modes could be mapped against the same design requirements.

Table 2: Course delivery modes and enrolments

Delivery Mode	**Enrolments**
Canberra Based	36
Incorporating EWB Summit	8
Total	46

In order to ensure that the students who participated in the course through the Summit delivery mode achieved the same learning outcomes as those participating through the Canberra based mode a course adaption and mapping exercise was completed. This established the topics that would not be covered adequately as part of the Summit and therefore would have to be covered through supplementary sessions when the students were in Canberra. Certain topics were not covered on the Summit because the content was not deemed to be pertinent to the Cambodian context or because there was not time to cover all topics in sufficient detail. The large advantage of the Summit was that students did not only learn the theory for a particular topic but were also able to put theory into practice in the field whilst in country. Table 1 highlights this mapping and adaptation of the course to incorporate the Summit.

Canberra Delivery

The Canberra based delivery consisted of four weeks of contact followed by a week of assessment and presentations. Each week of delivery had approximately two full days and one half day of delivery, supported by online resources. A mix of learning activities were used each day including practical activities, class discussions delivered like tutorials, guest lectures and seminar style delivery of content. Three site visits were also distributed over the four weeks. The delivery of topics is shown Table 1 highlight which day(s) of which week(s) a topic was delivered.

Summit Delivery

This mode consisted of three main stages, an initial workshop at the ANU before the summit, attending the two week Summit in Cambodia, then a return workshop back at the ANU. This face-to-face delivery was supplemented by additional resources particularly readings and videos. The Canberra-based course coordinator did not attend the Summit but delivered the initial and return workshops and was responsible for all assessment items. Table 1 provides an outline of the Summit for the course topics. In total there were 40 participants on the Summit, from a number of different Australian universities. The Summit was conducted over four distinct phases:

Phase One: all participants completed workshops in Phnom Penh covering basics of humanitarian engineering and attended cultural experiences.

Phase Two: the participants divided into three groups and spent three and a half days living in and working with a local community organisation in rural Cambodia. With guidance and support from facilitators, the students used participatory design to develop a number of technologies and ideas that could potentially solve the issues raised by the host community. Importantly, the participants supported community representatives to develop their own designs, therefore promoting ownership and knowledge transfer.

Phase Three: cultural exposure and design were the focus with participants, back together as one group, spending three days in Siem Reap (home to the temples of Angkor) working on their community designs and sharing experiences, as well as participating in workshops on personal development.

Phase Four: in Phnom Penh and provided the participants with time to finalise designs, utilising local markets and services to create working prototypes of their designs. With host community members present, the participants presented their designs and instructional material for discussion and to promote knowledge transfer.

Discussion

The curriculum development approach was selected to make it potentially easier to deploy the course in a different mode or at a different institution. The resulting curriculum design and development process was highly structured and required significant time during the course design phases as individual learning outcomes for each topic needed to be developed. However once those were determined, additional flexibility was enabled in how those outcomes could be met through specific learning activities. The ability to use the resulting course structure for different delivery instances was highlighted by the course being delivered in two parallel modes; one as a five week intensive over the mid-year break on campus at the ANU and the second incorporating the EWB Humanitarian Design Summit in Cambodia. Both modes of delivery allowed for an interactive and experiential classroom where students engaged with guest speakers, averaging one guest a day, field trips and build sessions.

Although the delivery approach was selected to support the dissemination of course material, the structure and course developed still needed to be accepted by students. Student comments from anonymous course exit surveys indicate they responded positively to material, delivery and structure with feedback including:

> *much more engaging than courses during normal semester*
>
> *The days at university were broken up into many different activities: lectures, build activities, guest lectures, group discussions. This structure made the course very engaging.*
>
> *It allows you to focus and really engage with the course*

A course in 4 weeks was excellent - information was condensed and I do not feel my learning was compromised. Wouldn't be comfortable taking other courses at the same time.

Students were also highly receptive to the mode of delivery incorporating the Summit with feedback including:

EWB Summit was an amazing experience and taught me so much - we did many workshops and the on the job experience working in the community was a highlight

The combination of the Summit and in-class (pre and post-summit) allowed a great insight into Humanitarian Engineering and also a real-life experience of the context we were placed in.

EWB aims to embed people-centred values and approaches into engineering curriculum and so disseminating information about the course and materials was became an essential component of the project. Information is being shared broadly to universities across Australia via email and open-source resources on EWB's website (see www.ewb.org.au/humeng-curriculum). The website is structured according to the topics presented here (in Table 1) so that users can download the course outline, topic list and learning outcomes. Different resources under each topic are listed allowing the user to choose what would be most suitable for their course. By interchanging guest speakers and field visits with those applicable to the local context of the institution course coordinators can ensure that the content is relevant to their cohort. Finally a call to contribute resources is included so that the library can grow with the HEE community in Australia.

The second mode of delivery, incorporating the Summit, makes adoption of the course by other institutions simpler as EWB delivers a large section of the course while providing a unique experiential learning environment in the field where students work on design projects alongside a community partner. The host institution is then responsible for introductory and return sessions and student assessment.

Conclusions and Further Work

To enhance the potential for a new course focusing on humanitarian engineering in Australia to be shared, disseminated and adopted, a specific curriculum development approach was utilised. This required additional time to be spent detailing and document the course design and structure, but ensured the resulting material could be readily adapted and modified. This potential was tested by piloting a course in two parallel delivery modes, one entirely in Canberra the other involving an in-country design program supported by EWB. The approach used and the pilots conducted highlight the ability to use the course design and material to adapt delivery to local settings including delivery mode, duration, engineering disciplines and research strengths. EWB and the ANU will be working with universities into the future to adapt the new course to further embed it into engineering curriculum.

References

Amadei, B., and Wallace, W. A. (2009). Engineering for humanitarian development. *IEEE Technology and Society Magazine*, *28*(4), 6–15.

Blanchard, B. S., and Fabrycky, W. J. (2010). *Systems Engineering and Analysis*. Prentice Hall

Campbell, R. C., and Wilson, D. (2011). *The Unique Value of Humanitarian Engineering*, AC 2011-2701, American Society for Engineering Education.

Faulconbridge, R. I., and Dowling, D. (2010). Systems approach to engineering education design. In *Proceedings of the 2010 Systems Engineering/Test and Evaluation Conference (SETE 2010)*. Systems Engineering Society of Australia.

Felder, R. M., and Brent, R. (2013). *Active and Cooperative Learning*. Workshop Notes, April 22, 2013, RMIT.

Goldfinch, T., Ilango, A., Roland, A., and Willis, J. (2014). *Australian Indigenous Culture and Heritage in Engineering Project Planning and the Implications for Engineering Education*. Proceedings of the Australasian Association for Engineering Education Annual Conference, Wellington, NZ.

Heywood, J. (2005) *Engineering Education - Research and Development in Curriculum and* Instruction. New Jersey, IEEE, John Wiley & Sons.

Hill, S., and Miles, E. (2012). *What do Students understand by the term 'Humanitarian Engineering'?* Innovation, Practice and Research in Engineering Education, September 2012.

Leydens, J. A., and Lucena, J. C. (2014). Social Justice: A Missing, Unelaborated Dimension in Humanitarian Engineering and Learning Through Service. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, *9*(2).

O'Shea, J., Baillie, C. and Armstrong, R, (2012). *Developing Critical Thinking Skills and an Understanding of Social Justice in Engineering Education*. Proceedings of the Australasian Association of Engineering Education, Dec 2012.

Nilsson, L. (2015) How to Attract Female Engineers - NYTimes.com. Retrieved 21 May 2015, from http://www.nytimes.com/2015/04/27/opinion/how-to-attract-female-engineers.html?_r=0

Nilsson, L., Madon, T., and Sastry, S. S. (2014). Toward a New Field of Development Engineering: Linking Technology Design to the Demands of the Poor. *Procedia Engineering*, *78*, 3–9.

Ramsden, P. (2003). *Learning to Teach in Higher Education*. Oxon, RoutledgeFalmer.

Smith, J., and Browne, C (2014). *A Program Level Approach to Community-Centred Engineering Education*, Proceedings of the Australasian Association for Engineering Education Annual Conference, Wellington, NZ.

Toohey, S. (1999). *Designing Courses for Higher Education*. Berkshire, SRHE and Open University Press.

VanderSteen, J., Baillie, C., and Hall, K., 2009. International Humanitarian Engineering - Who Benefits and Who Pays? *IEEE Technology and Society Magazine*, Winter 2009.

Acknowledgements

The authors wish to thank all those who provided input, comments and feedback into the course, including its development and delivery. Thanks also to all the students who undertook the course and provided us with feedback. Support for this project has been provided by the Australian Government Office for Learning and Teaching. The views expressed here do not necessarily reflect the views of the Australian Government Office for Learning and Teaching.

Copyright

Chapter 4: Integration of a Short-Term International Humanitarian Engineering Experience into Engineering Undergraduate Studies

Foreword

This Chapter provides a conference paper outlining the methods used to integrate the two-week international study-abroad EWB Humanitarian Design Summit (EWB Summit) into students' program at the ANU. The previous Chapter outlined the design of a new dedicated course, Engineering for a Humanitarian Context (EfaHC), which the EWB Summit could be incorporated into, allowing students to undertake pre- and post-trip workshops and assessment and receive full course credit (6 credit units, ¼ of a full-time semester study load) for the subject towards their degree. This course was one of three options available to students to incorporate the EWB Summit into their studies that are explored in this Chapter. The other two involved existing course structures to support students participating in the EWB Summit, either to count for work experience or as part of a research project. These both used existing course codes (ENGN3100 for work experience and ENGN4200, ENGN4221, ENGN2706, ENGN3706, ENGN3712 or ENGN4712 for research projects).

The first EWB Summit was delivered in January 2015, with participants spending two weeks in Cambodia. Three ANU engineering students took part in this (all were female) and there have been ANU engineering students involved in every EWB Summit round since. The EWB Summit was an integral component of the Humanitarian Engineering (HumEng) pathway at the ANU and alternative ways to make it available for students to access and incorporate it into their studies needed to be explored and evaluated.

This Chapter focuses on the first overall research question, exploring curriculum approaches for HumEng education and how short-term international experiences can be integrated into a student's studies. It describes the EWB Summit and the relative advantages and disadvantages of the three curriculum approaches with respect to students' learning and program requirements. Primary data on student engagement and experiences with the three alternatives is provided in terms of student numbers and quotes, which addresses elements of the second research question. This Chapter demonstrates how the curriculum development undertaken in Chapter 3 worked as planned, enabling the EWB Summit to be incorporated into the EfaHC course.

Integration of a short-term international humanitarian engineering experience into engineering undergraduate studies

Abstract

Many of the humanitarian engineering education initiatives in Australia are developed and supported by Engineers Without Borders Australia (EWB-A). These include the EWB Challenge, an embedded first year coursework program, and the Undergraduate Research Program, providing service-learning opportunities for later year individual or group projects. These represent the extremes of an undergraduate degree, leaving a significant gap in the program for a student interested in humanitarian engineering. A link is required to support student learning in humanitarian engineering between these extremes. To fill, the EWB Humanitarian Design Summits were developed. These are two-week international experiences combining facilitated workshops, cultural experiences and a community visit. They provide opportunities for students to engage in a scaffolded community based humanitarian engineering experience. They are available to mid-program students to optional take and are designed to be a lead into later year service-learning projects. At one Australian university a range of curriculum methods have been used to incorporate the experience into students' formal program including work experience, research projects and a for-credit course. These have created different outcomes, with those more tightly integrated into a students' program providing greater opportunities for student learning.

Introduction

Humanitarian engineering education and related areas including global engineering, development engineering and engineering for social justice, have expanded rapidly since the year 2000. Formal undergraduate qualifications in humanitarian engineering are now available in countries including the USA (such as those at Colorado School of Mines[1], Penn State[2] and Ohio State[3]), the UK (including Coventry University[4]) and as of 2016, New Zealand (University of Canterbury[5]). Central to many humanitarian engineering education programs are service learning or learning through service (LTS) initiatives. These support opportunities for students to engage with communities, individuals or organisations and provide a service which will have benefits for the partner in addition to student learning outcomes[6]. These also provide benefits for recruitment and retention of students particularly from under-represented groups within engineering[7].

The expansion of humanitarian engineering education initiatives and service-learning opportunities has been supported by a range of volunteer, not-for-profit and community groups. Significant among these have been numerous independent Engineers Without Borders (EWB) organisations established since 2000, notably EWB Canada (founded in 2000), EWB UK (2001), EWB USA (2002), EWB Australia (2003), EWB New Zealand (2008) and EWB-Asia (2014). In Australia, many of the humanitarian engineering education initiatives and service-learning opportunities are developed and supported by EWB Australia (EWB-A). These include the EWB Challenge, an embedded first year coursework program, and the Undergraduate Research Program, providing service-learning projects for later year individual or group work. These represent the extremes of an undergraduate degree, leaving a significant gap in the program for a student interested in humanitarian engineering. In addition, it was observed that students undertaking a final year project often did not have a relevant background in development or people-centred approaches. Without this, students often took a strong technical focus in their final year capstone project, often at the expense of other contextual or people-centred factors, as observed in other studies and programs[1].

A link was required to support humanitarian engineering student learning between the extremes of a students' program. This link needed to provide scaffolded and structured activities to provide learning on communication, design and development approaches particularly leading into substantive or immersive service-learning projects. To fill this perceived gap, the EWB Humanitarian Design Summits were developed. These are two-week international experiences combining facilitated workshops, cultural experiences and a community visit. This is available to mid-program students to optionally undertake and are designed to be a lead into later year service-learning projects. A range of approaches have been used by universities to incorporate the experience into students' formal program including work experience, research projects and for-credit courses. This paper will provide an overview of the EWB-A Humanitarian Design Summits and their implementation within a undergraduate engineering program at a single institution in Australia. A summary of EWB-A's humanitarian engineering education programs will first be provided, including the EWB-A Summit. How these are incorporated into an undergraduate program at the Australian National University (ANU) will be described. Results in the form of student engagement on the first three Summits of 2015 will be provided, followed by a discussion of the initial results and impacts, as well as plans for further integration, evaluation and research.

EWB Australia Programs

EWB-A was established as an independent national EWB in 2003. It places around 20 volunteers a year with partner organisations in Australia, South and South-East Asia including Cambodia, India, Nepal and Timor-Leste. International volunteer placements are typically 12-24 months per placement with all costs to the volunteer covered and a living allowance provided. Volunteers are placed with host partner organisations ensuring the opportunity for capacity building and multiple placements if required. EWB-A supports a significant education program focusing on students in Australia. At an undergraduate engineering level, two well established programs are the EWB Challenge and the EWB Undergraduate Research Program, with the EWB Summit being offered for the first time in January 2015.

The EWB Challenge targets first year students and aims to provide an introduction to engineering through a humanitarian engineering project. Each year, one partner organisation is a focus for the Challenge, with a range of topics, challenges and resources identified with the partner. These are provided to universities to incorporate into first year classes as appropriate for their needs and context. In 2015, the EWB Challenge was used by almost 30 universities in Australia reaching around 10,000 first year engineering students, about 60-70% of the total first year undergraduate engineering population in the country. The EWB Challenge has been delivered internationally in the UK, Ireland and NZ, with over 50 universities in total being involved around the world in 2015. With such large numbers of students involved, there is no direct engagement between students and the partner organisation and community members. Resources are provided by EWB-A and if further detail is required an EWB-A volunteer placed with the partner sources the necessary information. At the end of each year, universities nominate up to four student reports which are provided to EWB-A. These are summarised and a portfolio of concepts and ideas provided to the partner organisation for them to select any that appear relevant, interesting or require further work. Further evaluation of the EWB-A Challenge has been undertaken since it started in 2007[8].

The EWB Research Program is a project-based service-learning initiative to support capstone courses[6]. EWB-A works with its partners and volunteers to identify projects suitable for final year engineering undergraduate or masters coursework students. These are not the first priorities for the partners, as those are the focus of volunteer placements, but common motivations for partners proposing and supporting projects include:

1. time available, partners are typically focused on implementation and on the ground work with very limited time for research, feasibility studies or design improvements.
2. additional expertise, both in terms of undertaking quality research and depth of specialist engineering knowledge.
3. access to equipment and resources, to enable controlled lab and experimental work to be undertaken making use of specialised equipment that would otherwise unavailable.
4. to think in different ways, by engaging with students and academics who can look at an organisation and its work with fresh eyes or a different perspective.

In 2015, EWB-A scoped and offered around 50 project topics. These are allocated to interested academics to supervise or students to incorporate into their studies, with some adaption for specific academic requirements and expertise being made. Students primarily work with an academic supervisor at their home institution, with support from EWB-A current or returned volunteers as required and possibly partner organisations. While many projects require little direct engagement with the partner organisation, all should incorporate relevant development models, appropriate technology principles, and build on a people-centred approach. At the end of the project the students' academic requirements, typically a thesis or research report, are provided to EWB-A and the partner, along with an appropriate open-access summary. Some projects have also completed articles for the open-access Journal of Humanitarian Engineering[9].

The EWB Summit was designed in 2014 with the first Summit conducted in January 2015. These are two-week international experiences to a single country. Typically 40-50 undergraduate students take part on each Summit, supported by three facilitators, three mentors and up to three academic mentors. The Summits commence with four or five days of workshops and cultural immersions, typically in a major urban centre. Topics covered include community development principles, people-centred design, and cross-cultural communication. These provide preparation for the next phase of the Summit, a four to five day community visit, typically in a rural area. Summit participants are separated into three groups, each with a facilitator and one or two mentors, and visit a different community partner organisation. Within these visits, teams of three to five are formed to explore concepts for ideas, opportunities or challenges the partner has. Student teams are supported by the facilitator and mentors, providing a scaffolded way to experience development and people-centred design. All the student participants meet again to spend another four days working on their concepts and further cultural immersions. Each team then presents their concept, including a prototype and summary documentation, to the community partner.

Although community partners can take on-board any concepts or ideas, there is no aim or expectation that development and implementation work will be carried out as part of the Summit. This is captured in the Summits aims which include *supporting community partners by generating ideas for their project*. Other aims include *practise and promote two-way knowledge sharing* and *embedding people-centred values and approaches in engineering,* *technology and design education and practice*. These aims remove some of the pressures and expectations that can be present in programs and trips that are built around implementation[10] as well as potential ethical questions about unqualified engineering students working on implementation projects in overseas countries[11]. Further development or implementation can be supported by EWB-A's Development program by qualified professionals (although volunteering their time) in consultation with the partner organisations.

A significant factor in the support, accessibility and growth of the Summits has been financial assistance from the Australian Federal Government. This was first through the previous Governments' *AsiaBound* program (2013-2014), replaced by the current Governments' *New Colombo Plan (NCP)* (from 2014). The NCP is a competitive funding pool with a number of programs, one of which can provide universities with scholarships of up to A$3,000 to support a short term experience in the Indo-Pacific (Asia-Pacific) region. Universities can apply individually or in consortium's, for blocks of 10 scholarships to be used over 1 or 3 years. These scholarships can only be used by domestic (Australian) students. The total cost of taking part in a Summit includes the program, which covers all facilitation, accommodation, travel, insurance and food, with international airfares then an additional expense. Support from NCP scholarships typically covers about 60-70% of all these costs. Previous experience with EWB-A student work has highlighted covering 100% of the costs can have a negative impact, with the experience then seen as 'free' and students taking part regardless of the actual aims or their interests.

Humanitarian Engineering Education Incorporation into Coursework

As with all EWB-A education initiatives it is for each university to determine exactly how they are utilised within coursework programs. As one of EWB-A's formal university partners, the Australian National University (ANU) has been an early adopter of all of EWB-A's education initiatives. The EWB Challenge has been used in the first year introduction to engineering course since it was launched in 2007 while the EWB Undergraduate Research Program was piloted at the university in 2008 before being rolled-out across Australia. ANU was successfully with 10 scholarships from the only round of the AsiaBound program, which were used for the first three Summits in January, June and July 2015. An additional 20 scholarships from the first NCP round will support students for the 2016 Summits and 40 scholarships have been secured from the second NCP round to support students on Summits from 2017 through to mid-2019. In 2014 ANU and EWB-A were successful with a joint competitive education grant to develop a dedicated later year humanitarian engineering course called *Engineering for a Humanitarian Context* (EfaHC) course, which was the first of its type in Australia[12]. This was aimed at students in the second half of their four-year degree, and in particular those who had enjoyed the EWB Challenge in their first year and may be interested in undertaking a capstone project in their final year with EWB-A or a similar organisation.

EWB Summit Course Integration

With student funding available for the EWB Summits in 2015, the various ways it could be incorporated into a students' studies were explored. One requirement of the NCP is it must be aligned to a course that students can enrol in. The two expected ways were as work experience or contributing to a research project. However, as the new EfaHC course was to be offered for the first time as an intensive over the winter (June-July) break in 2015 at the same time as an EWB Summit to Cambodia, it was decided to use that offering of the EWB

Summit towards the EfaHC course requirements and learning outcomes. This meant the Summit was available to engineering students at ANU through the options below. A summary of the assessment tasks for the options is provided in Table 1.

1. to contribute to the *work experience* requirement. All students must complete 12 weeks equivalent work experience in order to meet their degree requirements. The Summit can be used to contribute 80 hours of work experience as a number of the facilitators and mentors on each Summit are qualified engineers.
2. directly as part of the final year individual capstone *research project*. All students must complete an individual research project, contributing 25% of their final years' coursework load. The Summit can be used to provide background or context for the project, or in a small number of cases, direct data collection, analysis and testing.
3. through a dedicated *for-credit course*. Students can undertake the Summit to contribute to the EfaHC course. Students complete one and a half days of workshops and three assignments before the Summit, with an additional day workshop and three assignments upon returning from the Summit.

Table 1: Assessment tasks for the curriculum integration options for EWB Summits.

Option	**Assessment**	**Due**
Work Experience	• Summative 5-page work experience report summarising work completed.	• once all 12 weeks of work experience completed by student.
Research Project	• 6-page midterm report • 50-page thesis	• end of first semester of project (½ way) • end of second semester of project (project completion)
For-Credit Course (EfaHC)	• 3-page Australian Development Context research report • 1-page Humanitarian Engineering Reflection • 3-page appropriate technology workshop report • 4-page Design Concept Proposal • 3-page Development Perspectives (Stakeholder) report • Humanitarian Engineering Portfolio (artefact consumable in 15mins)	• before Summit • before Summit • before Summit • completed on Summit, submitted upon return • 4-weeks after Summit • 4-weeks after Summit

Outcomes

The EWB Summits commenced at the start of 2015, with three Summits to Cambodia in January, June and July. Based on student interest and demand, and further support from NCP funding, five Summits are planned over the long 2015/16 summer break, three to Cambodia and two to India. Across the first 8 Summits, students from 24 different universities in Australia are taking part. The number of students who have taken part in Summits at the ANU and the different options they have selected to integrate the experience into their studies is shown in Table 2. Advantages and disadvantages of the various options are provided in Table 3, while specific examples of the options are provided below.

Table 2: Number of students at ANU for each course integration option.

Summit (date country)	Course Integration Method		
	Work Experience	Research Project	EfaHC Course
January 2015 Cambodia	3		
June 2015 Cambodia	1	1	8
December 2015 Cambodia	1		
December 2015 India			1
January 2016 Cambodia	1		2
February 2016 Cambodia	2	2	2
February 2016 India			1
Total	8	3	14

Table 3: Advantages and disadvantages of the three options for EWB Summit inclusion.

Option	Advantages	Disadvantages
Work Experience	• No course fees for students as a 0 credit unit value. • Contributes 80 hours of work experience when can be difficult finding work experience with qualified engineers.	• No structured reflection or input from teaching staff or direct assessment items. • Students 'paying' for work experience through cost of Summit.
Research Project	• Provides field work component. • No additional course fees for students.	• Limited to only a small number of days at one point during project. • Only used as part of the research project, no structured reflection on the students' experience or their specific role.
For-Credit Course	• Structured reflection and linking to assessment items supported by workshops before and after Summit trip. • Can access additional government loans for their first overseas education experience.	• Students need to pay standard course fees for undertaking course in addition to cost of Summit.

Work Experience Student: Two of the students on the first Summit to Cambodia in January 2015 used the experience to contribute 80 hours towards their work experience requirement. Once they have completed the required 12 weeks, they will submit a description of their learning as part of a work experience report. Upon returning, one the students provided the following quote:

On the trip I learned how a systems engineering approach is needed to solve complex problems, and to apply the systems principles I had learned in class in a practical and unfamiliar environment. The workshops taught me not only about basic humanitarian engineering principles, but also about the Cambodian culture. Participating in the trip has let me meet a wide range of people, both peers and professionals, who I would not have the chance to meet usually. I hope to continue applying what I learned on the trip throughout my studies and professional career.

Both these students went on to enrol and complete the EfaHC course in June/July 2015, one achieving the highest mark in the class. Both are now currently volunteering with the local chapter of EWB-A. For these students, completing the EfaHC course after the Summit allowed them to use the Summit as a base for some of their assessment items and allowed them to reflect on the experience in a much more formal and structured manner than only through the work experience report:

After going on the EWB Humanitarian Design Summit in Cambodia I wanted to learn more about humanitarian engineering. EfaHC gave me the chance to build on what I had learnt in the summit, and was just as engaging and hands-on as the summit.

Research Student: Two students will be undertaking the Cambodia Summit in February 2016 as a direct link to their final year individual capstone research project. One of the projects is with a Cambodian organisation working on accessibility and inclusion for people with disabilities, and involves developing initial designs for a wheel-chair accessible tuk-tuk (motor-cycle powered transport). The project has been scoped by the organisation and an EWB-A in-country volunteer. For this project, attending a Summit was set as a requirement. The student will be able to visit the partner, see their current operations and transport available, and discuss their goals and aspirations for the project. The student will be accompanied by the EWB-A in-country volunteer to ensure appropriate communication and expectations. The student in this case is already an active member of EWB-A, and the project is allowing them to pursue further studies in an area of interest to them.

Course-Credit Student: All eight students who attended the June 2015 Cambodia Summit as part of the EfaHC course were able to utilise the experience for their assessment including the final portfolio assignment. The opportunity to reflect on their experience within the context of the assessment tasks was significant. A number of prototypes made while on the Summit were re-made for submission, and allowed the students to submit a 'tested' engineering concept for review along with feedback from potential users (the community partner). Specific comments received from these students included:

The combination of the Summit and in-class (pre and post-summit) allowed a great insight into Humanitarian Engineering and also a real-life experience of the context we were placed in.

Doing the course alongside the Human Design Summit allowed me to more deeply and critically engage with the summit, and ultimately made the experience more enriching

As a participant of the recent design summit to Cambodia, I incredibly valued the opportunity to partake in the course 'Engineering for a Humanitarian Context.' Not only was I able to understand the theoretical concepts of designing for vulnerable, disadvantaged and marginalised individuals and communities, but I was then also given the tools to sensitively and appropriately expand my vision as to the role of a humanitarian engineer.

By combining the [EfaHC] *course with the Engineers without Borders Humanitarian Design Summit in Cambodia, I was able to apply the courses content to a real life situation and develop my community consultation and engagement skills whilst having the opportunity to travel and engage with like-minded students.*

Multiple Engagements: During 2015, one student highlighted the potential benefits of multiple engagements with EWB-A initiatives to construct an informal specialisation in humanitarian engineering. The student completed the EWB Challenge in their first year, so had been exposed to humanitarian engineering, and then during 2015 undertook two Summits, the EfaHC course and a final year research project. On the initial Summit in January 2015 the student spoke with a number of community organisations during their community visit around solar energy, which was the students' discipline major. This lead to a final year research project being scoped between the university, EWB-A and the community partner to explore the feasibility of household solar PV systems to supplement or replace the use of car batteries for lighting and phone re-charging. The student then attended the June 2015 Summit as part of the EfaHC course and as a student mentor for EWB-A. During this time, they sourced two small scale solar house systems based on their initial research and discussions with in-country suppliers. On the community visits for the Summit the student ran a number of workshops on solar PV and supported the installation of the two systems, one at the local school the other at a house (see Figure 1). The student was supported by a number of participants from the Summit during this time. The student then supported the community organisation through the initial monitoring of the systems, both of which are still in use 6 months after installation.

Figure 1: Students (in grey) conducting workshops on solar power at the local school (left) and the household system being installed by community members (right).

Based on their experiences, the student then applied for an EWB-A volunteer role in Cambodia specifically created to support the Summits and the potential further development of any concepts developed from them. The student was successful with this application, and within a month of completing their studies in November 2015 commenced a 20 month placement in Cambodia with EWB-A, being judged as the most appropriate candidate through the open competitive recruitment process.

The work is being continued by another student for their final year capstone project, after they attended the same June 2015 Summit, where they helped with the workshops and installation. This provides the opportunity for longer-term programs rather than just individual one-off projects.

As highlighted, an aim of the Summits is to support community partners by generating ideas for their aspirations and goals, which are available to community partners to use and further develop. From the first three summits to Cambodia in 2015 approximately 35 designs have developed, prototyped and presented from community visits. Of these, it has been observed that five concepts are known to have been further developed or implemented by the community partners. One example is shown in Figure 2. This prototype was developed with a partner working to re-establish mangrove plantations. This work involves collecting mangrove seeds and planting them in a bag filled with mud in order to geminate before being planted out. This is currently done by hand and is time-consuming. The concept developed by the student team on their community visit used waste water bottles and available pvc pipe to provide a way of filling the bags by placing the bag under the bottle to serve as a funnel (on the left of Figure 2). As can be seen on the right-hand side, although the specific prototype developed was not being used, the concept has been adopted and modified by the partner. This is now actively used and has reduced by half the time to fill each bag.

Figure 2: Mud bag filler, with the prototype concept developed by students on the left and the design as implemented by the partner on the right, with the prototype in the background.

Discussion

The rise in the number of well-organised engineering-related community groups over the last two decades has led to an increase in the opportunities for service-learning and extra-curricular activities for engineering students. While some opportunities have been relatively easy to align with formal coursework requirements, such as capstone design or research projects[7], others have been more challenging to incorporate due to existing coursework requirements and constraints such semester schedules, timetabling and existing demands on students[1]. Integrating curricula learning through service programs and related extra-curricular activities has been recently piloted through the EPICS and EWB-USA student chapters[13].

The EWB Summit can be considered both extra- and intra-curricular. It can be undertaken by a student to contribute to work experience because they are interested in humanitarian engineering or development work, or it can be the focus of a dedicated for-credit course. From the initial mostly informal feedback received and observations made, students incorporating the Summit for course-credit are gaining the most significant learning outcomes. The student comments from the June 2015 Summit and the students from the January 2015 Summit who then undertook the EfaHC course all highlighted the opportunity to connect theory and concepts with practice and direct community engagement as significant. The return workshop and assessment items enables a structured de-brief and empowers students to discuss any concerns or questions they still have. Integration through the course provides an appropriate structure better aligned with the aims of the Summit, which match requirements of other similar courses[1]. It also provides an opportunity to expand students' thinking by introducing further concepts such as human rights and engineering and social justice[14].

Although only one example has been completed so far, the combination of the Summit for course credit with a following research project, especially when linked to EWB-A volunteer placements, has achieved outcomes far beyond any expectations. From the one completed example, household level solar PV systems have been introduced to a rural part of Cambodia and the student involved has been able to transition directly into a volunteer humanitarian engineering placement. With multiple scholarships already secured through to mid-2019, there is the opportunity to build longer projects and programs. For instance, it can be almost guaranteed that there will be students attending EWB Summits in Cambodia at least once every 6 months for the next 3½ years. This enables a long-term plan to be developed around community aspirations and provides regular face-to-face contact with partners to discuss opportunities and project work. This allows all those involved to start to move beyond just considering projects that can fit into a semester as well as supporting good 'NGO partnering' as work can be established in similar way to longer-term programs[1].

EWB-A's role in organising and delivering the Summits provides a critical mass of students across universities rather than individual universities needing to organise and prepare trips. Summits build on ongoing EWB-A community partnerships rather than universities needing to development and manage those. This approach makes the implementation of a for-credit course to support the Summit at multiple universities simpler. The bulk of the 'course' is provided by EWB-A through the Summits, while universities are responsible for any pre- and post-workshops and assessment tasks. Participants also report the value of engaging with students from other universities and disciplines, to explore interdisciplinary practice.
A higher than average female participation in the Summits has been observed, similar to other initiatives and studies[13]. Of the 125 engineering students to participate in the first three EWB Design Summits in 2015 (at the time of writing), 62 (49%) have been women. This is consistent with the percentage seen across all EWB-A initiatives and activities which is typically around 45%. Of the 14 students to undertake or plan to undertake the Summit for course credit at the ANU six are women, giving 43% involvement compared to the base percentage of women in engineering which is around 20%.

As highlighted, the aim of the Summits is not to develop and implement new technology or engineering. However, from the 35 concepts or prototypes developed by students on the first three summits, five are known to have been incorporated or improved and are being used by partner organisations, which represents one new concept for development per Summit.

Conclusion and Further Work

The EWB Humanitarian Design Summits are providing opportunities for students to engage in a scaffolded community based humanitarian engineering experience. Approaches and learnings are being shared across Australian universities to contribute to the development of the Australian humanitarian engineering sector. Support from Federal Government funding through the NCP makes this more sustainable and enables integration of extra- and intra-curricular activities in a more structured manner. In the second and most recent round of the NCP program announced in 2015, twelve Australian universities received a total of 245 short-term scholarships to support students take part in EWB Summits in 2016 with Summits planned for Cambodia, India and Nepal. The work here, particularly integrating the Summits into a for-credit course, is of interest to these universities. This also contributes significantly to the development of a humanitarian engineering pathway for Australian engineering students, as originally intended, by providing engagement between the broad based EWB Challenge in first year and final year capstone projects.

In terms of the curriculum integration, students need to have the opportunity to incorporate Summits in some way while balancing the flexibility of opportunities (for example fitting into busy programs and work experience and internships) with achieving appropriate student outcomes. However, it is emerging that integrating the Summit through a dedicated for-credit course with the potential of undertaking a related research project provides the most significant student, and potentially community partner, outcomes.

Within the broader context of the EWB Summits, other elements of further evaluation are currently underway or planned. All student participants are being surveyed before, immediately after and again 6 months later on their views on engineering and social responsibility, with the first analysis due later in 2016. Additional investigation is planned on the involvement of the community partners involved. This has been incorporated into the EWB-A placement that commenced in November 2015 (by the student who undertook two Summits), to allow for data collection and short- and medium-term impacts. The role of the Summits as part of a broader humanitarian engineering program or pathway is part of the PhD studies of the lead author at the ANU.

Bibliography

[1] Dean, J. H., and Van Bossuyt, D. L. (2014). Breaking the Tyranny of the Semester: A Phase-Gate Sprint Approach to Teaching Colorado School of Mines Students Important Engineering Concepts, Delivering Useful Solutions to Communities, and Working on Long Time Scale Projects. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, 222–239.

[2] Dzombak, R., and Mehta, K. (2014). Scholarly Advances in Humanitarian Engineering and Social Entrepreneurship: A Typology of Research Publications. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, 98–116.

[3] Passino, K. M. (2009). Educating the Humanitarian Engineer. Science and Engineering Ethics, 15(4), 577–600.

[4] Hill, S., and Miles, E. (2012). What do Students understand by the term ‘Humanitarian Engineering’? Innovation, Practice and Research in Engineering Education, September 2012.

[5] UC Engineering (n.d.) *Diploma in Global Humanitarian Engineering*, http://www.engf.canterbury.ac.nz/humanitarian/ last accessed January 1, 2016

[6] Bielefeldt, A., Paterson, K., and Swan, C. (2009). Measuring the Impacts of Project-Based Service Learning. *American Society for Engineering Education*.

[7] Zoltowski, C. B., and Oakes, W. C. (2014). Learning by Doing: Reflections of the EPICS Program. *International Journal for Service Learning in Engineering*, Humanitarian Engineering and Social Entrepreneurship, 1–32.

8 Cutler, S., Borrego, M., and Loden, D. (2011). An Evaluation of the Australian Engineers Without Borders Challenge from the Course Coordinators Perspectives, 41st ASEE/IEEE Frontiers in Education Conference, October 12-15, 2011, Rapid City, SD.

[9] Maxted, B. (2012). Dust masks for Indian quarry workers: A comparative analysis of the filtering efficiency of fabrics. *Journal of Humanitarian Engineering*, 1 (1) 2012.

[10] Lewis, R. S. (2014). Insights from a Global Engineering Outreach Course. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, 256–268.

[11] VanderSteen, J., Baillie, C., and Hall, K. (2009). International Humanitarian Engineering - Who Benefits and Who Pays? *IEEE Technology and Society Magazine*, Winter 2009.

[12] Smith, J., Turner, J., and Brown, N. (2015). Design for Dissemination - Development of a Humanitarian Engineering Course for Curriculum Sharing. *Proceedings of 26th Annual Conference of the Australasian Association for Engineering Education (AAEE 2015).*

[13] Oakes, W. C., Zoltowski, C. B., Schmotzer, Katherine, & Valenca, Ana Paula. (2015). Integration of Curricular and Extra-Curricular Learning Through Service. Presented at the *122nd ASEE Annual Conference & Exposition*, Seattle.

[14] Leydens, J. A., and Lucena, J. C. (2014). Social Justice: A Missing, Unelaborated Dimension in Humanitarian Engineering and Learning Through Service. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, 9(2), 1–28.

Chapter 5: Intensive Mode Teaching of a Humanitarian Engineering Course to Enhance Service-Learning

Foreword

The Chapter completes the trilogy of publications focused on the design, delivery and evaluation of the first instance of the Engineering for a Humanitarian Context (EfaHC) course at the ANU. Building from the previous two Chapters which outlined the design, development and integration of EfaHC, this Chapter provides a journal article with a detailed evaluation of the first delivery in an intensive mode during the winter session of 2015. The course was delivered in two parallel modes to two student cohorts. The majority were completing EfaHC as a five-week special topic intensive elective in Canberra only, although it included a number of off-campus site visits and tours. A second, smaller cohort undertook the two-week EWB Humanitarian Design Summit study-abroad experience as part of the course. All students had the same learning outcomes, assessment items, topics and expected commitment (in terms of hours), with participants on the EWB Summit completing many of the topics while on the Summit rather than in Canberra. This approach was made possible due to the design of the course (outlined in the previous two Chapters) and the decision to deliver it in an intensive mode that coincided with the timing of EWB Summits.

This is the first Chapter to focus on the second and third research questions, investigating the students engaging with the HumEng pathway created and any outcomes achieved. A number of methods are used to assess EfaHC across the delivery mode (intensive teaching), key learnings achieved, and comparison between the two student cohorts. These cover both qualitative and quantitative methods, with the publication a mixed-method study in its own right. Aspects of the course evaluation were completed as part of a multi-university project led by the University of Western Australia focusing on intensive mode teaching. This allowed a greater range of data collection and analysis to be undertaken, with outcomes generated for both Humanitarian Engineering Education (HumEngEdu) and intensive teaching in engineering education.

The initial delivery of EfaHC was a key milestone in the growth of HumEngEdu in Australasia. It was the first time a dedicated, later year elective course with a focus on HumEng had been designed and delivered to a typical class size. Along with the study-abroad EWB Design Summit, it marked the start of step increase in HumEngEdu experiences and opportunities available to engineering students in Australasia. The course and EWB Summits filled a perceived gap between the introductory first year EWB Challenge and the final year EWB Undergraduate Research Program. The ANU students participating in the EWB Summit as part of EfaHC were also the first students in Australia to have the experience count directly for course credit, rather than for work experience or a research project.

International Journal for Service Learning in Engineering,
Humanitarian Engineering and Social Entrepreneurship
Vol. 11, No. 2, pp. 38-54, Fall 2016
ISSN 1555-9033

Intensive Mode Teaching of a Humanitarian Engineering Course to Enhance Service-Learning

Jeremy Smith
The Australian National University
Canberra, ACT, Australia 2601
jeremy.smith@anu.edu.au

Paul Compston
The Australian National University
Canberra, ACT, Australia 2601

Sally Male
The University of Western Australia
Perth, WA, Australia 6009

Caroline Baillie
The University of Western Australia
Perth, WA, Australia 6009

Jennifer Turner
Engineers Without Borders Australia
Melbourne, Victoria, Australia 3011

Abstract - **Service-learning is a common component of many humanitarian engineering education programs. Students engage with external organisations and communities, often spending time intensively, on projects linked to their studies. To help prepare students for substantial service-learning initiatives a dedicated humanitarian engineering course was developed. To better represent service-learning and enable a greater variety of teaching and learning activities, the course was delivered over five weeks using intensive mode teaching. This enabled a portion of the class to be involved with a two-week scaffolded immersive international experience running in parallel to the campus delivery. Threshold concept and capability theory was used to evaluate the course and identify what elements of the course supported or hindered development of student thresholds. Results identified the main student threshold to be *the ability to take account of social factors in engineering design* and the activities enabled by the intensive mode teaching were among the strongest contributions to the achievement of this threshold, in particular elements of the international experience. This highlights the opportunities for intensive mode teaching in supporting activities related to service-learning.**

Index Terms - Humanitarian engineering, intensive mode teaching, threshold concepts

INTRODUCTION

Service-learning is a component of most humanitarian engineering education programs and can take the form of field work[1, 2], international immersions[3], capstone projects[4] or across disciplines and year levels[5]. In addition to providing motivation, which is linked to better learning outcomes, service-learning has been shown to lead to more positive attitudes towards social responsibility[7], identity outcomes[8] and civic leadership[9]. Introducing student engineers to service-based projects and community development work can be challenging but is required to ensure students act responsibly, particularly in later years when they may have greater roles[4].

To provide appropriate preparation for students progressing to more substantial service-learning experiences, a dedicated mid-program course focusing on humanitarian engineering was developed. To support this and enable activities more representative of service-learning

International Journal for Service Learning in Engineering,
Humanitarian Engineering and Social Entrepreneurship
Vol. 11, No. 2, pp. 38-54, Fall 2016
ISSN 1555-9033

it was decided to adopt an intensive mode teaching delivery. This allowed delivery of the course to two parallel cohorts, one campus-based the other utilising a short-term immersive international experience. A threshold concepts and capabilities framework was used to evaluate the student experience and outcomes through this teaching mode to assess the delivery method.

This paper first outlines the context and background for the work, including humanitarian engineering, service-learning and intensive mode teaching. The theoretical framework used to evaluate the intensive teaching mode, based on threshold concepts and capabilities, along with the research questions, is provided. The development of the course is outlined as well as data collection methods. Results and discussion are provided across the various data collection methods within the context of the course and theoretical framework with recommendations for other institutions and researchers.

CONTEXT AND BACKGROUND

Humanitarian Engineering Education

Humanitarian engineering education has grown rapidly since the early 2000's with established programs in the US[4] and UK[10] and emerging programs in Australia[11] and New Zealand. Related areas with intersecting elements but different philosophical frameworks including engineering for development[1], global engineering[3] and engineering for social justice[12] have also emerged. A discussion of the differences between these is beyond the scope of this paper, however some critiques of humanitarian engineering have explored potential "engineering for development" elements. Broadly, humanitarian engineering initiatives are seeking to prepare graduates to work on humanitarian development and response challenges and opportunities primarily with vulnerable, marginalised or disadvantaged groups or individuals. This places a strong emphasis on professional skills particularly team-work, cross-cultural competency and communication as well as interdisciplinary studies. Critiques of this field particularly from a social justice perspective have considered an inappropriate focus on technology, exclusion of social and power imbalances and lack of consideration of structural forces[12].

Service-Learning

To provide opportunities for authentic learning and support humanitarian engineering education, most include a component of service-learning. These seek to provide an opportunity for students to learn course material and content while providing a "service" for an external community or partner, often a non-for-profit organisation. The student activity contributes to credit-bearing courses which provides the scaffold for assessment, feedback and reflection[7]. Students engage directly with external partners on an identified project and need, often spending significant time on activities outside formal class hours[13]. Service-learning initiatives are being incorporated more broadly into engineering education as a realistic and effective way for students to apply the theory of their studies to encourage deep learning and motivation as well as supporting academic and personal development[6, 7, 14].

As with humanitarian engineering, critiques of service-learning have considered advantages and limitations with the approach. In particular, questions of who benefits most and who provides the resources and commitments have been raised[15]. International service-learning experiences have been examined and placement specific liabilities identified[15], often linked to elements of social justice[12].

Humanitarian Engineering Education Pathway

Although not offering a formal qualification in humanitarian engineering, The Australian National University (ANU) has established a pathway for students to be involved in activities across all year levels. The ANU is a research intensive university on a single urban-campus established after the second world war with a low staff to student ratio and a significant focus on postgraduate studies. The four-year undergraduate engineering degree has a common systems engineering core, with a number of discipline majors in newer fields including renewable energy, mechatronics and communication.

For a number of years ANU has utilised service-learning through the EWB (Engineers Without Borders Australia) Challenge in first year, local project opportunities in second year, and capstone individual research and group design projects in final year. Leading into capstone experiences a perceived gap with students lacking background in humanitarian approaches and aspects of human-centred and participatory design had been observed. To fill this, and support student interest, a mid-program course on humanitarian engineering was proposed. This would cover humanitarian approaches, appropriate technology, and topics required for in-depth service-learning experiences in later years. While in development EWB launched its Humanitarian Design Summit program, two-week immersive trips to South-East Asian countries EWB worked in. These provide a scaffolded opportunity for students to be involved in development and humanitarian work supported by professional engineers and mentors[16]. Considering the objectives of the course and the opportunities for including the EWB Summits, it was decided to deliver the course using intensive mode teaching.

Intensive Mode Teaching

For the purposes of this study, intensive mode teaching involves students attending classes on fewer days and for longer on each day than is traditional in the discipline, often only enrolled in a single course at a time. Various models of the mode have been used in business and postgraduate law courses to allow study with minimal disruption to work[17]. It has been used in external courses with intensive periods on campus, and in courses in health sciences to allow students to fit classes between practicums. Although the above reasons provide the impetus to use intensive mode teaching, it has been found to provide additional benefits with students and teachers in two business units and an engineering unit reporting the following opportunities for[18, 19];

- students to learn from each other and bond in a learning community[20];
- extended interactive and practical activities; and
- exposure to practice such as real-world case studies and practical application of theory in authentic contexts.

These aligned with the objectives of the course in providing field trips and building a learning community as well as incorporating the international EWB Summits.

THEORETICAL FRAMEWORK

To investigate the impacts of the intensive mode teaching threshold concept theory and threshold capability theory were used.

Threshold Concepts

Threshold concepts are critical to future learning and practice in a discipline[21]. They are experienced by students as transformative and usually troublesome in one of many ways. It is important for curriculum designers and teachers to identify threshold concepts so that they can focus on these in the curriculum, particularly in-class time.

The theory proposes that students experience a state called the "liminal space"[21] while they still feel challenged by a threshold concept. The liminal space is rarely traversed directly and it may take students longer than one course or even a whole program of study before they overcome a threshold concept. An example of this was the "Trusteeship" threshold from an engineering concept inventory[22]. This was developed from work identifying a "spectrum of liminality" for the threshold of using social justice as a lens for viewing engineering[23]. This has five positions from the pre- to post-liminal positions connected to a threshold with nine conceptions and students' progress through the spectrum in different ways.

Threshold concepts were used in a phenomenographic study that identified seven qualitatively different student categories of understanding and experiencing of human-centred design (HCD)[24]. A strong threshold concept was identified as a transition between the two categories not included in the main nested hierarchy. Here students need to move from technology-centred views to one where user input feeds into a linear design process. Additional transformative aspects were identified in other higher-level categories.

Threshold concept theory was valuable for studying students' learning in this study as:

- the theory is about students' experiences of learning in addition to the learning intended by the teacher;
- the concept of traversing the liminal space is relevant to a mode in which it is likely that the opportunity to traverse the liminal space is limited by time; and
- their use in related engineering education as described above.

Threshold Capabilities

Threshold capability theory has emerged from a combination of threshold concept theory and capability theory[25] which proposes that students in higher education should develop capabilities to address previously unseen problems[26]. A threshold capability is transformative and challenging, and critical to future progress, as is a threshold concept. A threshold capability is likely to depend on understanding of one or more threshold concepts. The liminal space also applies to threshold capabilities.

Research Questions

Building on the theoretical framework established, three research questions were identified for evaluating the course:

1. what did students identify as thresholds for the course?
2. what features of the course hindered or supported their learning?
3. what were the benefits and limitations of the delivery mode as preparation for humanitarian engineering service-learning?

COURSE DEVELOPMENT

Course Design

The development of the course utilised a version of the systems engineering vee design process applied to education[11, 27]. First a set of learning outcomes were developed with input from external partners which was then peer-reviewed. These were used to drive the development of a set of course topics, each with corresponding learning outcomes, organised to give the structure of the course. The four main topics were Humanitarian Contexts, Humanitarian Approaches and Models, Personal Practice and Engineering Practice. Within these were 17 sub-topics and a total of 70 individual topics. Teaching and learning activities were developed to meet each individual topic's outcome, taking into account the opportunities presented by the intensive mode teaching. Constructive alignment was used to validate and align assessment, topics and outcomes. This approach resulted in a very fine level of course content detail meaning individual activities could be modified or changed as long as the outcomes were still met. This allowed the course to be delivered to two cohorts, one entirely based on-campus (although including site visits), the other off-campus incorporating the two-week international EWB Summit.

Course Delivery
The total number of students who undertook the course is shown in Table 1. All undergraduate students were enrolled in either a single four-year bachelor of engineering degree or a five-year double degree including engineering. The masters coursework students were all enrolled in a Master of Engineering program.

TABLE 1
STUDENT ENROLMENTS BY DELIVERY MODE AND DEGREE PROGRAM

Student Cohort	Enrolments
Campus Based - Undergraduate	36
Campus Based - Postgraduate	3
With EWB Design Summit - Undergraduate	8
Total	46

The course was available as a special topic, meaning enrolment was by approval of the course coordinator. The pre-requisites were either a bachelor's degree or two-years of undergraduate engineering. One exception was made to this, for a second year student, due to their significant background with development work and excellent academic performance. No students who had completed the pre-requisites were refused enrolment.

Course Delivery - On-Campus
The on-campus delivery was during the June-July winter term between the main teaching semesters. The course had four weeks of delivery, each with on average 2½ days of class time, followed by a week for completing and presenting assessment. A mix of learning activities was used each day, covering practical sessions, class discussions, seminars and guest presentations. The eight guests involved were drawn from engineering with significant humanitarian experience, non-engineers with backgrounds in development studies, and those with lived experience of humanitarian responses. Three site visits were conducted, all with an hour transit. Two of these were 2-3 hour visits to organisations involved with humanitarian work with discussions focused on their approach and operations. The other was a full day visit to a nature reserve, Birrigai, exploring Indigenous knowledge and undertaking a 'learning track' with an Indigenous Australian ranger.

Course Delivery - Off-Campus
Students incorporating the EWB Summit in the course had a different course structure although the same learning outcomes and assessment tasks[11]. Delivery consisted of a one-day workshop with students before they left. The Summit ran for two weeks in Cambodia, with a total of 40 participants from multiple universities around Australia. Participants started with workshops in Phnom Penh and engaged in cultural experiences. The Summit

split into three groups, each spending four days on a rural community visit working with a Cambodian-based community organisation. The focus was on human-centred design and identifying challenges and opportunities student teams could develop concepts and ideas for. The three teams then re-joined and spent further time working on their concepts. Finally, concepts were presented back to the community organisations for their consideration and feedback to support knowledge transfer and identify any potential next steps. For the course, students returned and completed another half-day workshop on campus and presented their final assignments with students from the campus-based delivery.

METHODS

Data collection methods are outlined in the sub-sections below in the sequence in which they were conducted, labelled for reference later in this paper. A two-phase approach adapted from one to identify threshold concepts and capabilities was used[28]. The first phase (B and C below) was exploratory and identified potential threshold concepts and capabilities. In the second refinement phase (G and H), identified thresholds were negotiated with the teaching team and reduced for a student survey. Data collected through student course evaluations (A, D-F) were used to support and validate findings.

Across all data collection, participants were drawn from the course only, and all participation was voluntary and anonymous. Ethics approval was provided by the home institution (for A, D-F) and the lead institution for the intensive mode teaching research (for B, C, G and H).

A. Student Entry Survey

An online entry survey was used to capture student background before the course. This included information to help shape elements of the course as well as enrolment motivations.

B. Interviews with Teaching Team

The course coordinator at the home institution and external person at EWB involved with development, as a content expert, were interviewed as part of the exploratory phase. Interviews were semi-structured, 45 minutes long and recorded and transcribed. The interviewer explained the theory to the participant. Interview questions were:

1. *What is your role in the unit?*
2. *In this role, have you noticed that students experience any threshold concepts in this unit?*
3. *What makes you think that students find this concept troublesome?*
4. *One or more threshold concepts can be combined to achieve a 'threshold capability'. With a threshold capability students can apply understanding of threshold concepts to previously unseen problems. Like threshold concepts, threshold capabilities are critical to future learning and practice in the discipline.*
5. *Can you think of a threshold capability in your unit?*
6. *Please think of one threshold capability that is especially troublesome.*
7. *What are you aware that students do to help them develop this capability?*
8. *What about the teaching and/or about students assists them to overcome the threshold?*
9. *What about the teaching and/or students hindered them in overcoming the threshold?*

C. In-class Student Workshop

Also in the exploratory phase, a 30 minute in-class workshop was held during week three of the class by an independent researcher, during which the course coordinator was not present. It was not recorded as students were able to participate without agreeing to take part in the study although the researcher did take hand-written notes. The researcher explained the theory to participants and facilitated a discussion asking open questions to ensure the students understood the theory. Students were invited to complete a questionnaire to collect demographic data and a second questionnaire containing the following questions:

1. *Please identify a threshold concept that you have experienced in the unit.*
2. *Please describe a threshold capability that you have experienced in the unit. It might be an application of the threshold concept identified above, or a different capability.*
3. *How was the capability troublesome?*
4. *What did you do to develop the capability?*
5. *Please identify any feature of the unit that helped you to develop the capability.*
6. *Please identify anything about you (such as your strengths, experience, or support) that helped you to develop the capability.*
7. *Please identify any feature of the unit that hindered you in developing the capability.*
8. *Please identify anything about you (such as your experience or commitments) that hindered you in developing the capability.*

Responses from B and C were analysed for evidence of potential threshold concepts or capabilities, how these were transformative and troublesome, and factors that supported and hindered overcoming them. Coding was managed using NVivo™ V10.

D. In-class Discussion

In the last session of the course an in-class feedback discussion was led by the course coordinator. Students identified course highlights, which of the course learning outcomes they felt they had achieved, and additional topics or ideas for inclusion.

E. Student Exit Survey

An anonymous paper based exit survey was used to capture student feedback. This was conducted after students had given their final assessment presentations.

F. Student Course Evaluations

All courses at ANU are required to incorporate two formal course evaluations, student experiences of learning and teaching. These are anonymous online surveys with a combination of 5 point scales and open ended questions set by the university. Separate surveys are used for undergraduate and postgraduate students, as assessment items and criteria vary slightly for these cohorts. The survey is opened after the delivery of the course and closed before final results are released.

G. Post-Completion Focus Group with Teaching Team

After the students had received their results for the unit, the course coordinator and external person at EWB were interviewed together for 45 minutes. In this interview they were presented with themes identified in the exploratory stage. They clarified features of the course mentioned by students and reduced the themes to a selection of items for a student survey. This included the main threshold capability and features raised by students as supporting and hindering them in overcoming thresholds in the course.

H. Post-Completion Student Survey

Students in the course were invited by email to complete an online survey. The survey included demographic questions and the questions below designed to assess the extent to which participants experienced the identified main threshold capability as transformative and challenging. The items were developed directly from the theory, the exploratory phase in this study, and themes identified in other intensive mode engineering and business units[19].

RESULTS

Results are provided below across three main activities, from the exploratory phase on threshold concepts (methods B and C), from the post-completion threshold capability student survey (H), and the student input methods (A, D to F). Response rates are provided in Table 2 giving overall rates and distributions for students involved in on- and off-campus (attended the EWB Summit) delivery while demographic profiles for each method are summarised in Table 3. Method F could not include a question on delivery mode as this was a standard university-wide evaluation.

TABLE 2
DATA COLLECTION RESPONSE RATES AND DISTRIBUTION FOR ON- AND OFF-CAMPUS DELIVERY

		N	Response Rate %	Distribution % of Respondents
A. Student Entry Survey	**Overall (potential participants 46 students)**	**37**	**80.4**	
	Did Not Attended Summit As Part of Course	36	94.7	93.0
	Attended Summit As Part of Course	1	12.5	7.0
C. In-Class Workshop	**Overall (potential participants 38 students on-campus)**	**28**	**73.7**	
	Did Not Attended Summit As Part of Course	28	73.7	100.0
	Attended Summit As Part of Course	0	0.0	0.0
D. In-Class Discussion	**Overall (potential participants 38 students on-campus)**	**21**	**55.3**	
	Did Not Attended Summit As Part of Course	21	55.3	100.0
	Attended Summit As Part of Course	0	0.0	0.0
E. Student Exit Survey	**Overall (potential participants to all 46 students)**	**39**	**84.7**	
	Did Not Attended Summit As Part of Course	33	86.8	84.6
	Attended Summit As Part of Course	6	75.0	15.4
F. Course Evaluation	**Overall (potential participants 43 undergraduates)**	**17**	**39.5**	
H. Post-Completion Survey	**Overall (potential participants 46 students)**	**20**	**43.5**	
	Did Not Attended Summit As Part of Course	12	31.6	60.0
	Attended Summit As Part of Course	8	100.0	40.0

International Journal for Service Learning in Engineering,
Humanitarian Engineering and Social Entrepreneurship
Vol. 11, No. 2, pp. 38-54, Fall 2016
ISSN 1555-9033

TABLE 3
PARTICIPANT DEMOGRAPHIC PROFILES

A. Student Entry Survey	**Characteristic**	**N**	**%**
	Respondents and response rate (available to all 46 students)	37	80.4
	Year Level		
	First	0	0.0
	Second	1	2.7
	Third	7	18.9
	Fourth	25	67.6
	Fifth	1	2.7
	Masters Coursework	3	8.1
	Discipline Major		
	Electronic and Communication Systems	9	24.3
	Mechanical and Material Systems	24	64.9
	Mechatronic Systems	3	8.1
	Renewable Energy Systems	8	21.6
	Sustainable Systems	2	5.4
	Digital Systems and Telecommunications	2	5.4
C. In-Class Workshop	**Characteristic**	**N**	**%**
	Respondents and response rate (from 39 students on-campus)	28	71.8
	Gender		
	Female	9	32.1
	Male	19	67.9
	Enrolment		
	Domestic	14	50.0
	International	14	50.0
	Age range 20 to 26 years (*M* = 22.2 years, *SD* = 1.5 years)		
D. In-Class Discussion	**Characteristic**	**N**	**%**
	Respondents and response rate (from 39 students on-campus)	21	53.8
E. Student Exit Survey	**Characteristic**	**N**	**%**
	Respondents (available to all 46 students)	39	84.7
	Gender		
	Female	12	36.4
	Male	21	63.6
F. Course Evaluation	**Characteristic**		
	Respondents and response rate (from 43 undergraduates)	17	39.5
	Enrolment		
	Domestic	9	52.9
	International	8	47.1
	Full-time student	17	100.0
	Part-time student	0	0.0
H. Post-Completion Survey	**Characteristic**	**N**	**%**
	Respondents and response rate (available to all 46 students)	20	43.5
	Gender		
	Female	8	40.0
	Male	12	60.0
	Enrolment		
	Domestic	15	75.0
	International	5	25.0
	Age range 20 to 25 years (*M* = 22.0 years, *SD* = 1.2 years)		

Threshold Concept Workshop Themes

Themes indicating threshold concepts and capabilities are presented in Table 4. These were identified in the questionnaire responses from students from the in-class workshop (method C) for the following question: *Referring to the capability to take account of social factors in engineering designs, please rate your agreement with each of the following statements (1 = Strongly disagree; 5 = Strongly agree.)*

TABLE 4
THRESHOLDS EXPERIENCED BY STUDENTS

Threshold Concept	*Sample Comments*	*Comments*
Definition of humanitarian engineering	*The definition of humanitarian engineering encompassing development and disability, not just disaster relief.*	8
Relevance of social cultural and environmental context to engineering	*Understanding that different experiences, be it social, cultural, environmental, affect the engineering process.*	4

Threshold Capability	*Sample Comments*	*Comments*
Communication with others including non-engineers and other cultures and working together	*Being able to understand how to convey complex engineering situations to a whole variety of audiences.* *How I would actually work with a developing community*	6
Taking account of social and environmental context in engineering	*Cultural considerations and development approaches/frameworks. Being able to apply contextual knowledge and knowledge of culture to implement appropriate technologies* *Ability to identify when each approach may be appropriate, given the context of the problem, and how that changes the technology.*	6
Understanding the role(s) of a humanitarian engineer	*Understanding the role of a humanitarian engineer.* *Capability on how to apply basic concepts on humanitarian engineering (HE) into real-life product applications.*	6

The second of the capabilities in Table 4 was reduced to the more specific capability “to take account of social factors in engineering design” to provide the main subject to focus students’ attention on their experience of learning in the unit in the final student survey (method H). The more specific capability satisfied the principle for questionnaire designs that each question must ask only one clear question to avoid collecting responses with ambiguous meanings.

Threshold Capability Survey Results

The first survey questions in method H were to describe the generalisability of the experience of the capability ”to take account of social factors in engineering design” as a threshold by students in the unit. Results are presented in Table 5 including an overall 4 or 5 response rate for the class, as well as 4 or 5 response rates from students with on- and off-campus experiences, in addition to an exact significance test comparing the two cohorts’ responses for each statement.

TABLE 5

RATINGS OF AGREEMENT WITH STATEMENTS REGARDING THE CAPABILITY “TO TAKE ACCOUNT OF SOCIAL FACTORS IN ENGINEERING DESIGN” (*N* = 20)

Statement	**4 or 5 selected by student**	**% Overall**	**% On-Campus**	**% Off-Campus**	**p**
In this unit I developed the capability to take account of social factors in engineering designs	20	100	100	100	1.00
This learning transformed my thinking about engineering design.	19	95.0	91.7	100	1.00
This learning transformed my thinking about the kind of engineer I hope to be.	17	85.0	75.0	100	0.24
This learning challenged my previous assumptions.	13	65.0	50.0	87.5	0.16
I needed to commit much time for this learning.	9	45.0	50.0	37.5	0.67
The capability is still challenging for me.	4	19.0	16.7	25.0	1.00
Learning to communicate with people from outside engineering or other cultures was challenging.	8	40.0	16.7	75.0	0.02*
Understanding the meaning of engineering practice was challenging.	4	19.0	16.7	35.0	1.00
Understanding the meaning of humanitarian engineering was challenging.	9	42.9	41.7	50.0	1.00
Dealing with loosely defined problems was challenging.	9	45.0	33.3	62.5	0.36

Notes for Table 5:

1. Student rated statement on a five-point scale (1 = *strongly disagree*; 5 = *strongly agree*)
2. Items are listed in the order they were presented in the questionnaire.
3. *N* for on-campus was 12 (from 38 potential respondents) and off-campus was 8 (from 8 potential respondents).
4. *p* is calculated using Fisher’s exact test.
5. *p* of less than 0.05 are marked with an * and are considered significant.

Students responded to the following question for ratings of factors that supported and hindered their development of the capability ”to take account of social factors in engineering design” for items shown in Figures 1 and 2. *Please rate the extent to which each of the following factors influenced your development of the capability to take account of social factors in engineering designs (1 = Strongly hindered your development of the capability; 7 = Strongly supported your development of the capability). In the text boxes please explain any ratings of 1 or 7.*

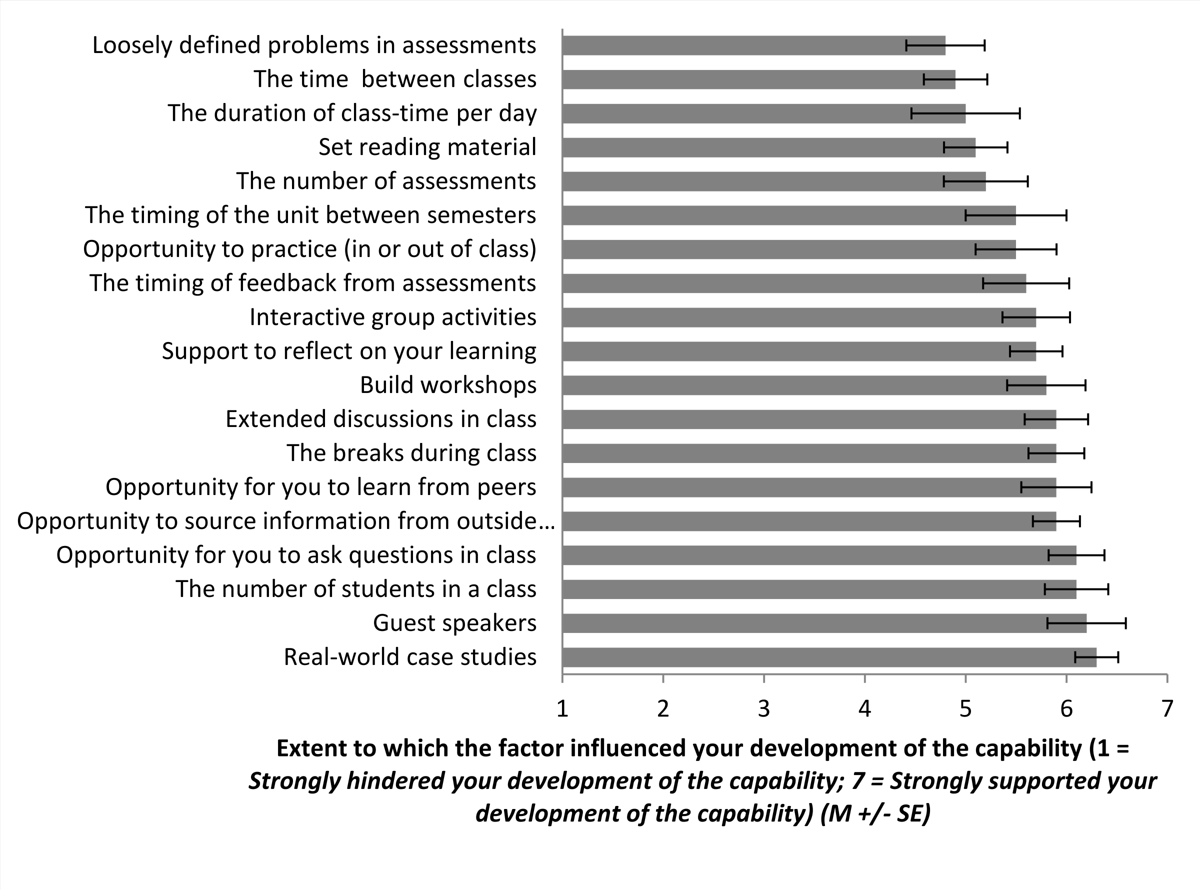


FIGURE 1
RATINGS OF THE EXTENT TO WHICH FACTORS INFLUENCED DEVELOPMENT OF THE CAPABILITY BY STUDENTS WHO DID NOT ATTEND THE EWB SUMMIT FOR THE UNIT (N = 10 FROM 38 POTENTIAL RESPONDENTS) (NO MISSING VALUES)

Student Input

The primary motivations of students from the entry survey, where students could only select one option, are shown in Table 6 and highlights more than half (56.7%) of the students were primarily interested in the topic of the course rather than the delivery mode or timing.

TABLE 6
PRIMARY STUDENT MOTIVATIONS FOR ENROLMENT

Primary Motivation	**N**	**%**
Interested in humanitarian engineering	12	32.4
Interested in the application of engineering to real-world problems	9	24.3
Reduced course load in semester 2	9	24.3
Convenience	3	8.1
Just need one course to finish studies	2	5.4
Other	2	5.4

Three separate methods provided data to identify the highlights or strengths of the course, the in-class discussion on the last delivery day (method D), the exit survey (E) after the final assessment item and the formal Student Experience of Learning (SEL) survey (F). Highlights identified from these as shown in Table 7.

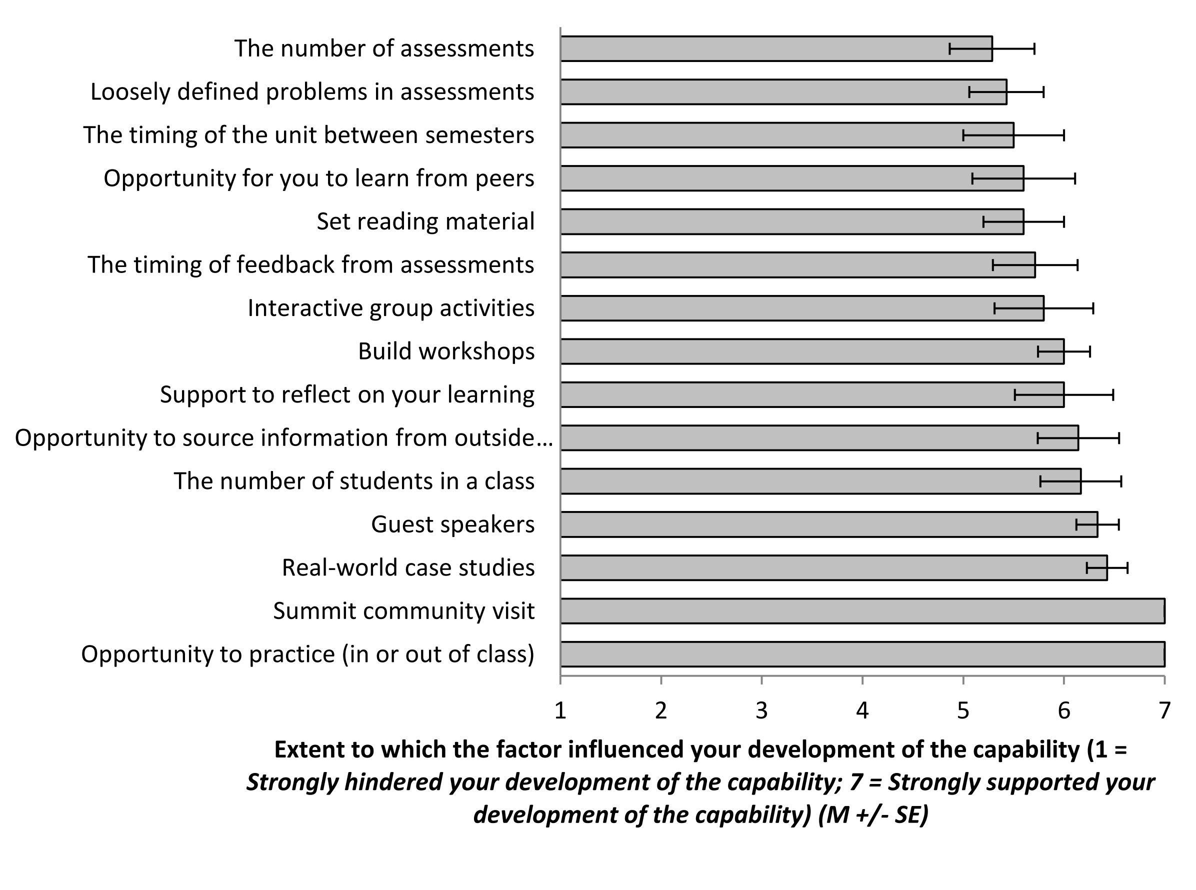


FIGURE 2
RATINGS OF THE EXTENT TO WHICH FACTORS INFLUENCED DEVELOPMENT OF THE CAPABILITY BY STUDENTS WHO ATTENDED THE EWB SUMMIT FOR THE UNIT (N = 8 FROM 8 POTENTIAL RESPONDENTS WITH 13 OR 12.4% OF MISSING VALUES)

TABLE 7
COURSE HIGHLIGHTS AND STRENGTHS IDENTIFIED BY STUDENTS

Course Highlight	Method Identify From
Birrigai Field Trip (Indigenous Focus)	In-class
Field Trips	In-class, SEL
Build Workshops	In-class, Exit Survey, SEL
Social Aspects (Learning Community)	In-class
Class Discussion Sessions	In-class, Exit Survey
Guest Lectures or Workshops	In-class, Exit Survey, SEL
EWB Summit	Exit Survey, SEL

The formal course evaluations are provided in Table 8, with the score out of 5 and the agreement rate consisting of those that ‘agree’ or ‘strongly agree’ with the question (4 or 5).

Only responses from undergraduate students are provided, as the three enrolled postgraduate students was less than the five required by the university to release results. As this was an university administered evaluation, a question on the delivery mode could not be included.

TABLE 8
FORMAL STUDENT EVALUATIONS OF THE COURSE

Evaluation	Score (out of 5)	Agreement Rate (%)	Response Rate (%)
Experience of Learning (SEL)	4.8	100	40
Experience of Teaching (SET)	4.9	100	40

Key limitations or areas for improvement for the course identified by students were mostly on assignments including the clarity of rubrics, expectations and time available, the latter of which is a function of the intensive teaching mode.

DISCUSSION

The strong formal student evaluations in Table 8 as well as the exit survey and in-class discussions and results from Table 5 indicate the course provided new learning for students. Results are discussed below corresponding to the three research questions posed for the study.

Thresholds Identified

The results indicate the capability identified, "to take account of social factors in engineering design", was a threshold, as students had not previously considered taking social factors into account in their engineering design. Responses from the post-completion survey (method H) and Table 5, confirm that the capability was transformative for 95.0% of the student survey participants and troublesome for 65.0% of students survey participants. Furthermore, a majority (81.0%) of the students no longer found the capability challenging and therefore had probably traversed the liminal space for this capability by the end of the course. The reasons students found the capability troublesome varied, as highlighted by Figures 1 and 2.

Differences between students who attended the EWB Summit (off-campus) and those who did not (on-campus) can been seen in Figures 1 and 2, and Table 5 where a trend can be seen. Those who attended the EWB Summit had potentially a more challenging but richer learning experience. However, only one statement can be considered significant, referring to learning to communicate was challenging. Students on the Summit were in a foreign culture with a different language, which required the use of translators which would have contributed to the significant difference between the two cohorts here.

The thresholds experienced by students were consistent with other studies. The main threshold capability relates to those identified in the threshold concept inventory[22] in particular the "Roles of engineers". This includes elements of "responsibility of engineers to society, the environment, and workers" and "value of an engineer to society and to organisations".

Contributions of Course Features to Learning

For campus-based students, a number of activities enabled by the intensive mode teaching were strong contributing factors to the development of capability. From Figure 1, site visits were the equal forth highest contributing factor. Other factors that can be incorporated into most teaching modes but are more easy to accommodate in intensive mode teaching scored well, specifically guest speakers (second highest) and opportunities to ask questions in class (third highest). Day or half-day face-to-face sessions provided more opportunity to accommodate guests and flexibility to change activities based on student engagement and interest such as further class discussion and questioning.

Across all students, the factor that was identified as contributing most to the development of the capability was the community visit undertaken in the EWB Summit (Figures 1 and 2). This highlights the role of external engagement in achieving the capability identified. Other activities that can support transformations here including real-world case studies, guest speakers and site visits, all scored highly in influencing the development of the capability. The exposure to real-world applications through guest lectures and case studies were rated most supportive for learning after the Summit (Figures 1 and 2).

Although the response rate for the post-completion survey was not quite half the class (43.5%), the findings from this method are supported by both the in-class discussions and exit survey (see Table 7). The findings are also consistent with existing work in the area with respect to intensive teaching mode[18, 20, 28].

Contributions of Delivery Mode to Service-Learning Preparation

The course was established to help prepare students for more substantial service-learning initiatives related to humanitarian engineering. The threshold capability identified, “to take account of social factors in engineering design”, appears well suited as a threshold to achieve as preparation for service-learning. In terms of students achieving this threshold and then moving to more substantive service-learning, a number of students participating in the course have gone on to take part in final year service-learning projects. Of the 43 undergraduates in the course, three were already involved in final year service-learning projects while four have commenced projects at the start of the 2016 academic year.

The inclusion of the EWB Summit in particular has aligned with the development of the pathway leading to service-learning experiences. From twelve students who undertook an EWB Summit over the 2015/16 Australian summer (not part of this study), five have commenced service-learning final year individual research projects in 2016 while another two will once they reach their final year in 2017. With the community visit on the Summit as the factor that most contributed to achieving the threshold this is appropriate preparation for students. The development of a student pathway may support opportunities for student development of thresholds from multiple engagements and opportunities to move through the liminal space[23].

Conclusions, Recommendations and Continuing Work

Intensive mode teaching was found to provide opportunities for significant contributions to the threshold identified by students for the course, “to take account of social factors in engineering design”. With these findings, the choice to deliver the course using intensive mode teaching is supported as the activities achievable made significant contributions to students’ development of the capability. The teaching mode supported the inclusion of the international EWB Summit which included a community visit which was the factor that contributed most to the capability development.

There is a need to evaluate students’ outcomes within the broader context of their overall studies. This needs to consider how the course provided preparation for later service-learning initiatives in terms of the outcomes achieved through the service-learning experience. This is the focus of current research at ANU with students involved in the course or who have attended an EWB Summit.

The research framework utilised here may have further benefit for evaluating service-learning. Many staff have observed the “transformative” nature of service-learning, and threshold concepts and capabilities may provide a framework to help identify key thresholds.

ACKNOWLEDGEMENT

The authors wish to thank all the students who undertook the course and provided feedback. Support was provided for the development and delivery of the course and the evaluation of the intensive mode teaching by the Australian Government Office for Learning and Teaching. The views expressed here do not necessarily reflect the views of the Australian Government Office for Learning and Teaching.

REFERENCES

[1] Sandekian, R., Chinowsky, P., & Amadei, B. (2014). Engineering for Developing Communities at the University of Colorado Boulder: A Ten Year Retrospective. International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship, 62–77.

[2] Colledge, T. H. (2014). Engineering and Engaged Scholarship at Penn State Part II: The Existing Ecosystem. International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship, 114–147.

[3] Pinnell, M., Daniels, M., Hallinan, K., & Berkemeier, G. (2014). Leveraging Students’ Passion and Creativity: ETHOS at the University of Dayton. International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship, 180–190.

[4] Bixler, G., Campbell, J., Dzwonczyk, R., Greene, H. L., Merrill, J., & Passino, K. M. (2014). Humanitarian Engineering at The Ohio State University: Lessons Learned in Enriching Education While Helping People. International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship, 78–96.

[5] Zoltowski, C. B., & Oakes, W. C. (2014). Learning by doing: reflections of the EPICS program. International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship, 1–32.

[6] Bielefeldt, A., Paterson, K., & Swan, C. (2009). Measuring the Impacts of Project-Based Service Learning. American Society for Engineering Education.

[7] Bielefeldt, A. R., & Canney, N. (2014). Impacts of Service-Learning on the Professional Social Responsibility Attitudes of Engineering Students. International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship, 9(2), 47–63.

[8] Bielefeldt, A., Paterson, K. G., & Swan, C. W. (2010). Measuring the Value Added from Service Learning in Project-Based Engineering Education. International Journal of Engineering Education, (3), 535–546.

[9] Astin, A. W., Vogelgesang, L. J., Misa, K., Anderson, J., Denson, N., Jayakumar, U., Yamamura, E. (2006). Understanding the effects of service-learning: A study of students and faculty. Report to the Atlantic Philanthropies, 1–155.

[10] Hill, S., & Miles, L. (2012). What do Students understand by the term ‘Humanitarian Engineering’? In Innovation, Practice and Research in Engineering Education (pp. 1–11). Coventry University, UK.

[11] Smith, J., Turner, J., & Brown, N. (2015). Design for Dissemination - Development of a Humanitarian Engineering Course for Curriculum Sharing. In *26th Annual Conference of the Australasian Association for Engineering Education (AAEE1015) Order of Proceedings*.

[12] Nieusma, D., & Riley, D. (2010). Designs on development: engineering, globalization, and social justice. Engineering Studies, 2(1), 29–59. http://doi.org/10.1080/19378621003604748

[13] Bielefeldt, A., Paterson, K. G., Swan, C. W., Pierrakos, O., Kazmer, D. O., & Soisson, A. (2013). Spectra of Learning Through Service Programs. Presented at the 120th ASEE Annual Conference and Exposition, Atlanta.

[14] Duffy, J., Barry, C., Barrington, L., & Heredia, M. (2009). Service-learning in engineering science courses: Does it work? In American Society for Engineering Education. American Society for Engineering Education.

[15] Vandersteen, J. D. J., Baillie, C., & Hall, K. (2009). International humanitarian engineering. *IEEE Technology and Society Magazine*, 28(4), 32–41.

[16] Smith, J., Turner, J., Brown, N., & Price, J. (2016). Integration of a short-term international humanitarian engineering experience into engineering undergraduate studies. In *ASEE's 123rd Annual Conference and Exposition*.

[17] Davies, W. M. (2006), "Intensive teaching formats: A review", *Issues in Educational Research,* Vol. 16 (1), pp. 1-18.

[18] Crispin, S., Hancock, P., Male, S. A., Baillie, C., MacNish, C., Leggoe, J., Alam, F. (2016). Threshold capability development in intensive mode business units. *Education & Training, 58*(5). pp 1-23, doi: 10.1108/et-02-2016-0033

[19] Male, S. A., Baillie, C., Alam, F., Crispin, S., Hancock, P., Leggoe, J., Ranmuthugala, D. (2016). *Students' experiences of threshold capability development with intensive mode teaching*. Paper presented at the 39th Annual Conference of the Higher Education Research and Development Society of Australasia (HERDSA), Fremantle, Western Australia.

[20] Wenger, E. (1998). *Communities of Practice - Learning, Meaning and Identity*. New York: Cambridge University Press.

[21] Meyer, J. H. F., & Land, R. (2003). Enhancing Teaching-Learning Environments in Undergraduate Courses Occasional Report 4 Retrieved 31 May 2010, from http://www.etl.tla.ed.ac.uk/docs/ETLreport4.pdf

[22] Male, S. A. (2012). Engineering Thresholds: an Approach to Curriculum Renewal Final Report. Sydney: Australian Government Office for Learning and Teaching.

[23] Kabo, J., & Baillie, C. (2009). Seeing through the lens of social justice: a threshold for engineering. *European Journal of Engineering Education, 34*(4), 317 - 325.

[24] Zoltowski, Carla B., William C. Oakes, and Monica E. Cardella. 'Students' Ways of Experiencing Human-Centered Design'. *Journal of Engineering Education* 101, no. 1 (1 January 2012): 28–59. doi:10.1002/j.2168-9830.2012.tb00040.x.

[25] Bowden, J. A. (2004). Capabilities-driven curriculum design. In C. Baillie & I. Moore (Eds.), *Effective learning & teaching in engineering* (pp. 36-47). Abingdon, Oxon: RoutledgeFalmer.

[26] Baillie, C., Bowden, J. A., & Meyer, J. H. F. (2013). Threshold Capabilities: threshold concepts and knowledge capability linked through variation theory. *Higher Education, 65*(2), 227-246.

[27] Faulconbridge, R. I., & Dowling, D. (2010). Systems approach to engineering education design. In *Proceedings of the 2010 Systems Engineering/Test and Evaluation Conference (SETE 2010)*. Systems Engineering Society of Australia.

[28] Male, S. A., & Baillie, C. A. (2011). *Threshold Concept Methodology*. Paper presented at the Research in Engineering Education Symposium, Madrid.

Chapter 6: Student Engagement with a Humanitarian Engineering Education Pathway

Foreword

This Chapter and the next present results investigating the Humanitarian Engineering (HumEng) pathway at the ANU as a whole. The Chapter presents a journal article addressing the second research question in particular, detailing results from student engagement with the created HumEng pathway. Student engagement is considered from the point of view of enrolment, motivations, demographics, identity and study characteristics.

Analysis in the paper draws from multiple data sources, all linked to specific courses or initiatives across the HumEng pathway. The main focus is on dedicated HumEng initiatives, specifically the Engineering for a Humanitarian Context (EfaHC) course, short-term study-aboard experiences (including, but not only, the EWB Summit), and project-based experiences including research and group design courses. Generally anonymous pre- and post-experience surveys were used to collect a mix of quantitative and qualitative data, although in this Chapter the majority of the data presented is quantitative, generally drawn from pre-experience surveys. As highlighted in Chapter 1, data was collected from a broader group of students to allow for a comparison between students engaging in HumEng activities and an overall student baseline. Here, the baseline is all third and fourth year students enrolled in engineering programs at the ANU.

The publication provides an outline of HumEng education in Australia including EWB-A's national initiatives as well as other similar programs overseas, particularly the USA, Canada and the UK. The completed HumEng education pathway is documented including the year, delivery timing, opportunities, and how these related to data collection. A review of existing work and study designs used to evaluate similar initiatives is provided, which helped create the mixed-methods approach in this research as well as specific data collection tools and focus. Student enrolment data for HumEng education initiatives are provided, followed by detailed data comparing students engaged in key HumEng experience to the overall baseline. The discussion draws the various results and analysis together and identifies insights for student engagement and motivations.

AUSTRALASIAN JOURNAL OF ENGINEERING EDUCATION
2018, VOL. 23, NO. 1, 40–50
https://doi.org/10.1080/22054952.2018.1533396

ARTICLE

Student engagement with a humanitarian engineering pathway

Jeremy Smith[a], Andrea Mazzurco[b] and Paul Compston[a]

[a]Research School of Engineering, The Australian National University, Canberra, Australian; [b]Engineering Practice Academy, Swinburne University of Technology, Melbourne, Australia

ABSTRACT

The number of undergraduate degree programmes incorporating humanitarian engineering experiences and curriculum has increased significantly since the turn of the century. This paper describes a humanitarian engineering pathway embedded across all four years of an undergraduate engineering degree at an Australian university. Student participation in the pathway and their motivations were evaluated from quantitative enrolment data and anonymous surveys and compared to an overall student baseline. This found a higher percentage of students engaged in humanitarian engineering were female, domestic and involved in extra-curricular activities compared to the overall student baseline. Most students engaging with the pathway were motivated by opportunities to apply their engineering; some highlighting this was to have an impact on societal issues. Recommendations are made for research to further understand student engagement as well as suggestions for initiatives to address potential challenges as humanitarian engineering education continues to expand across Australasia.

ARTICLE HISTORY
Received 19 March 2018
Accepted 4 October 2018

KEYWORDS
Humanitarian engineering; service-learning; gender diversity

1. Introduction

1.1. Growth of humanitarian engineering

Since the first Ingenieurs sans Frontieres (ISF), or Engineers Without Borders (EWB), was established in France in 1982, there has been a steady increase in the number of organisations with aims to provide humanitarian or development assistance through engineering and technology (Nieusma and Riley 2010). Depending on location and focus this is variously called Engineering for Global Development, Development Engineering, Engineering for Developing Communities, or Engineering in Emergencies. In Australasia, as in some other countries, *Humanitarian Engineering* (HumEng) has emerged as the label for these organisations and their activities. In Australia, HumEng encompasses the broadest range of assistance, from disaster response and recovery to long term community development, both domestically and overseas (Greet 2014; Turner, Brown, and Smith 2015).

Alongside the growth in organisations has been the rise of higher education programmes incorporating HumEng. While formal programmes have been delivered internationally since the 1990s (Bratton 2014; Moskal et al. 2008), the growth of Humanitarian Engineering Education (HumEngEdu) in Australasia coincided with the introduction of the EWB Design Challenge in 2007 (Smith et al. 2017) by EWB Australia (EWB-A). EWB-A has been at the forefront of HumEngEdu in Australasia since, formally launching the EWB Undergraduate Research Program in 2008 and EWB Humanitarian Design Summits in 2015 (Smith et al. 2017). These programmes provide opportunities for universities to integrate HumEngEdu and engage students according to their resources, context and goals. This is happening rapidly, with no award programmes on offer in Australasia in 2015, increasing to six offered or planned by 2019 (Smith et al. 2017). While studies on HumEngEdu and related fields have been undertaken overseas, this has not occurred in Australia. An evaluation of programmes and student participation in Australasia is required to support student engagement and continued growth.

1.2. Research aims

The work presented here is part of a larger study investigating the development and delivery of an elective HumEngEdu pathway at the Australian National University (ANU). This paper explores student engagement with the pathway in terms of choice, participation and motivations, by investigating the following questions:

(1) What are the number and percentage of a student cohort participating with optional HumEng curriculum and initiatives.
(2) What are the characteristics and demographics of students participating with HumEngEdu.
(3) What are the motivations for students to be involved with HumEngEdu.

CONTACT Jeremy Smith jeremy.smith@anu.edu.au Research School of Engineering, The Australian National University, Canberra, Australian

The next section will outline HumEngEdu internationally, programmes in Australia, and the pathway developed at the ANU. The research design to gather student data will be provided along with findings on student participation and motivation. A discussion will reflect on student engagement and make recommendations for universities delivering or introducing HumEngEdu.

2. Humanitarian engineering education

2.1. Existing programmes

HumEngEdu and related programmes under a variety of terms (such as Development Engineering) have been offered since the late 1990s, particularly in the United States, Canada and UK. Offerings range from informal extra-curricular programmes often supported by external and student organisations (Bratton 2014), through certificate and award programmes such as minors (Moskal et al. 2008; Passino 2009), to a small number of named degrees at undergraduate and masters levels (such as the University College London Master of Science in Engineering for International Development). In almost all cases, programmes complement or build on a base engineering discipline. In this way, HumEng is a specific application of an engineering discipline rather than a discipline itself, which matches how it is viewed in Australia (seen in Greet 2014; Turner, Brown, and Smith 2015).

A broad range of curriculum approaches are utilised in HumEngEdu, with study abroad (Berg, Lee, and Buchana 2016), learning through service (LTS) (Bielefeldt et al 2013; Duffy et al. 2009) and project-based learning (PBL) (Bratton 2014) common. These are integrated into curriculum depending on individual institution needs and requirements (Bielefeldt et al 2013). Benefits to students from these experiences include understanding of ethical practice and corporate social responsibility (CSR) (Bielefeldt and Canney 2014), professional skills (Bratton 2014; Duffy et al. 2009; Pierrakos et al. 2013) and global awareness (Moskal et al. 2008).

Studies have identified challenges for HumEngEdu including cost, support, and preparation for students (Moskal et al. 2008; Passino 2009). Programmes and experiences must ensure they do not reinforce inappropriate development practices or power relationships. As highlighted by Vandersteen, Baillie, and Hall (2009), a focus on only international development and student outcomes can be detrimental for partner organisations and communities, and reinforce benefits of privilege. There is a danger the outcomes for participating students, such as personal and professional development and learning, can be given higher priority than benefits for partner organisations and communities, which may be providing relatively substantial resources and commitments. Other work including Nieusma and Riley (2010) and Leydens and Lucena (2014) have critiqued views of community development and disadvantage within HumEngEdu and highlighted the need to incorporate concepts of social justice. This includes educating students on broad systemic issues that underlie disadvantage, as well as integration of social justice principles directly into the design and delivery of education programmes.

2.2. Initiatives in Australia

EWB-A provides three programmes for universities to integrate into their programmes (Smith et al. 2017). The EWB Challenge and EWB Undergraduate Research Program both utilise a service-learning (SL) approach, where student learning is recognised for course credit.

EWB Challenge: targeted at first year engineering. A design brief is prepared by EWB-A and one of its community partners each year identifying opportunities and challenges by discipline. Supporting material and resources are provided which institutions incorporate according to course aims and resources. From the student work, universities identify design reports which are fed back to EWB-A to share with the partner to develop a pool of concepts.

EWB Summits: a two-week study abroad experience providing an introduction to community development, HumEng and Human-Centred Design (HCD). The programme includes workshops, community homestays, cultural immersions and the opportunity to apply HCD to develop ideas for a host community organisation. During 2018, Summits were held in countries including Nepal, Cambodia, India and Malaysian Borneo. Students pay EWB for the cost of the Summit, which can be offset by Federal Government New Colombo Plan (NCP) scholarships. These typically cover 60–70% of the cost but are only available to domestic students, who can also access Government Loan programmes through OS-HELP.

EWB Undergraduate Research: provides topics for final year individual and group research and capstone projects. Topics are identified by EWB-A and partner organisations in Australia and overseas, which universities and students apply to undertake. EWB-A receives the research to disseminate to partners and the sector broadly.

University specific programmes have been emerging since 2015 and are beginning to be evaluated. Johnson et al. (2017) provide reflections on approaches for undergraduate students to contribute to HumEng projects while Thomas et al. (2017) document lessons learnt from the development of the first HumEng award programme in Australia, which commenced at the University of Sydney in 2017. These works provide insights to the development of opportunities and curriculum but do not provide data on student participation or engagement, highlighting the need for the research here within the domestic context.

2.3. Pathway design and structure

The engineering programme at the ANU provided an appropriate base for HumEngEdu for a number of reasons. It is offered through a single School delivering two four-year degrees, a Bachelor of Engineering (BE) and a higher entrance Bachelor of Engineering (Research and Development (BE(R&D)). Both consist of a systems engineering compulsory core from which seven discipline majors are available. A significant amount of project work is included in the first three years of the core courses, while in final year all students undertake both dedicated individual research and group capstone projects. Core courses cover topics including engineering and systems design and analysis, which can be applied to HumEng, while majors provide discipline depth. This aligns with the application-based understanding of HumEngEdu.

The pathway was developed over a number of years as opportunities arose, starting in 2007 and completed by 2015, with the finished pathway shown in Figure 1. It was developed by embedding EWB-A programmes and a small number of targeted electives and experiences typically within the common core using approaches such as PBL and SL (see Table 1). Students engage with the pathway by selecting HumEng project topics in core courses and then undertake dedicated experiences such as the Engineering for a Humanitarian Context (EfaHC) elective and study-abroad experiences.

3. Research study

The study design to investigate student engagement with the HumEng pathway at the ANU is outlined followed by the specific data collection methods. The work here to investigate student engagement is part of a larger study into student experiences using a mixed-methods approach. This paper only describes the quantitative elements that capture student engagement with

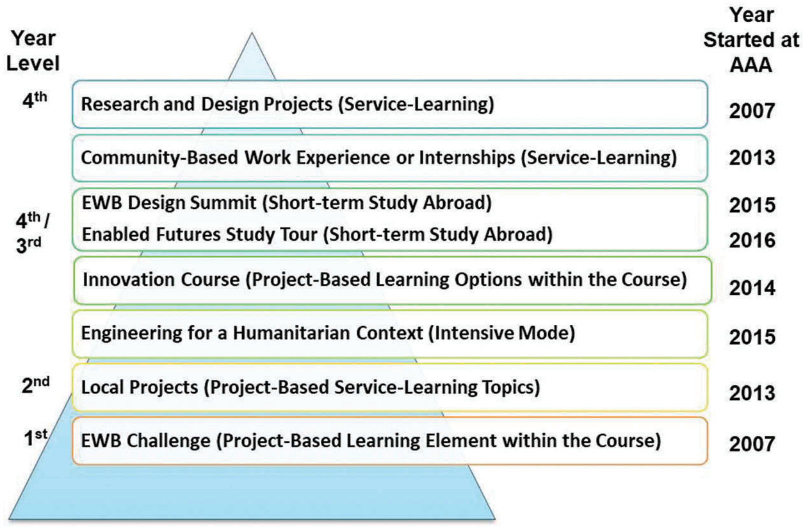


Figure 1. HumEngEdu pathway components across year level including programme, curricular approach (in parentheses) and year commenced.

Table 1. Details of HumEngEdu components linked to course delivery and opportunity (Y = Year, S = Semester).

Pathway Component	Course Pathway is In	Delivery (Year and Semester)	Opportunity, Projects, Content
EWB Challenge	ENGN1211	Y1, S1	EWB Challenge for all students.
Local Projects	ENGN2225/6	Y2, S1 and S2	Local projects focusing on access, inclusion and disability, and further EWB Challenge projects.
Innovation Course	ENGN3230	Y3, S2	Student generated ideas for social enterprises.
Community-Based Work Experience or Internship	ENGN3100/3200	Any	Work experience and internships with community-based organisations.
Engineering for a Humanitarian Context (EfaHC)	ENGN4520 Special Topic in Engineering	Y3 or Y4 Summer and Winter Sessions	6-unit elective delivered in intensive mode incorporating the EWB Design Summit, with pre- and post-Summit workshops and assessment.
EWB Design Summit, Enabled Futures	Integrated into various courses	Y3 or Y4 Summer and Winter Sessions	Short-term study abroad trips that can be incorporated into EfaHC, work experience or research and design projects.
Research and Design Projects	ENGN4200	Y4, S1 and S2	Individual research projects with external partners or applications of current research to humanitarian contexts.
Research and Design Projects	ENGN4221	Y4, S1 or S2	Group design and engineering projects with external partners.

the pathway in terms of participation and motivations. Student learning and outcomes from their engagement is being examined as part of the overall study, to be presented in later publications.

3.1. Previous studies

The overall design incorporated recommendations from mixed-methods studies on similar phenomena. Within a mixed-methods study, Berg, Lee, and Buchana (2016) used surveys to collect information relating to SL and its links to professional responsibility and ethics while collecting demographic information. A key recommendation was collecting data from a comparison group of students. Again using a mixed-methods approach, Pierrakos et al. (2013) found differences in areas of engineering identity, ethical and societal awareness, lifelong learning and real-world applications of projects for students involved with problem-based SL. Litchfield, Javernick-Will, and Maul (2016) explored the impacts of involvement with engineering service on engineering students and professionals. They found similarities in levels of technical skills but differences in professional skills, with those engaged in SL gaining greater outcomes in this area. Huff et al. (2013) investigated the influences of a large-scale SL programme in the United States on the views of design of its alumni. A quantitative survey completed by 523 participants captured broad characteristics and impacts on alumni. From the responses, a maximum variation sampling strategy was used to identify candidates of which 27 participated in interviews to explore their survey responses in more detail. While the specific findings were less relevant for this research, the methodology and sampling method and sizes provided lessons for the research here. In a more general study, Wilson et al. (2014) explored links between cocurricular activities and academic engagement, and their relationship with academic self-efficacy. They found interactions between them, based on the amount and nature of cocurricular efforts.

3.2. Study design

Previous studies identified demographics, non-study commitments, engineering identity, attitudes to study and career motivations as areas which can affect engagement related to SL and PBL and these become the focus for the data collection. A key aspect of student engagement and choice is related to career motivations. General motivations and career opportunities were identified in Kinash et al. (2015) in their study focusing on employability skills in Australia. Motivations specifically for HumEng were identified in studies including Duffy et al. (2009) and Litchfield and Javernick-Will (2016).

The focus of the quantitative elements in this research were third and fourth year students where the bulk of the study opportunities were available. Data were collected from multiple sources as detailed in Table 2. There were two broad participant pools, all students studying engineering at the ANU and a sub-set of those engaged with optional HumEngEdu. The former provided a baseline for comparison to the latter (as recommended by Berg, Lee, and Buchana 2016). This was achievable as all engineering students at the ANU are within a single School can take the same common core courses, hence students are exposed to the same influences, resources, structures and staff. In addition to enrolment and project selection data, three anonymous surveys were used; a profile survey for all students to provide the baseline and two targeted surveys for HumEng international experiences and research projects. The research was granted human ethics approval by the ANU.

Figure 2 shows the relationship between participants. In some cases, students may have completed a survey twice, or in a small number of cases, three times. However, students undertaking a HumEng experience need to be captured within the baseline group as well. Due to student patterns, some students undertaking a HumEng Research and Design Project or International Experience may have already completed their compulsory third and fourth year courses and hence will not be captured in the overall baseline. A fourth cohort from the profile survey was used for comparison, consisting of students who stated they had completed a HumEngEdu study abroad experience (highlighted in blue in Figure 2).

All three surveys had the same common base focusing on study, current commitments, past experiences, demographics, career motivations and engineering and study beliefs (see Table 3). The two HumEng surveys asked additional questions about motivations with the initiatives, with the International Experience survey

Table 2. Data-collection sources.

Data	Collection Type	Participants	Corresponding Research Question(s)
Course Enrolment	Enrolment data for elective courses	Engineering for a Humanitarian Context Course Students	1
Project Topic Selection	Project topics within compulsory courses	Students enrolled in ENGN4200, ENGN4221, ENGN3230	1
Student Profile Survey	Anonymous survey	Students enrolled in ENGN4221 and ENGN3230	1, 2
International HumEng Experience Survey	Anonymous survey	Students starting a HumEng international experience	1, 2, 3
HumEng Research Experience Survey	Anonymous survey	Students starting a HumEng research project in ENGN4200 or ENGN4221	1, 2, 3

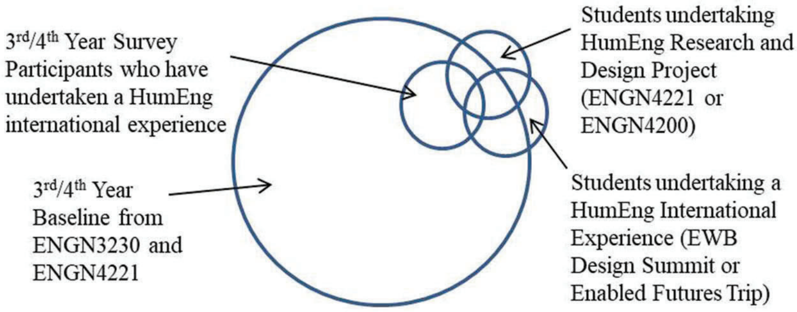


Figure 2. Relationships among survey participants.

Table 3. Elements and items within surveys.

Element	Focus	Number of Items	Surveys Used In
Study	Details of current study	Seven questions, one-word or Yes | No answers	All
International Background	Details of Upcoming International Experience	Ten questions, one-word or Yes | No answers	International HumEng Experience
HumEng Motivations	Reasons for undertaking a specific optional experience	Two ranking questions (1–4 scale), total 22 items	HumEng International Experience and Research
Career Motivations	Potential career aspirations	One 1–4 ranking question with 11 items	All
Commitments	Commitments outside formal studies	Three questions, one-word, scale or Yes | No	All
Past Experience	Previous study, work and extra-curricular experiences	Five questions, one-word or Yes | No answers	All
Demographics	Demographic characteristics	17 questions, one-word or Yes | No answers	All
Engineering Beliefs	Attitudes to engineering	One 1–4 ranking and 1–5 ranking questions, 23 items in total	All
Study Beliefs	Attitudes to study	Two questions with 1–5 ranking scales with 31 items in total	All

asking further questions relating to study abroad. Survey items were typically Yes or No, one-word responses (such as 'Current Degree'), Likert questions with a 1–5 scale (strongly disagree to strongly agree) and belief questions on a 1 (not important) to 4 (very important) scale. The base survey length was six pages, with the Research and the International Experience surveys seven and eight pages respectively.

Questions about commitments and past experiences were drawn from Wilson et al. (2014), allowing students to select from a wide range of university clubs and societies as well as indicating their maximum hours volunteered per week (on a scale of 0–40) and role, from *member* to *leadership*. Wilson et al. (2014) contributed to questions about engineering and study beliefs along with Pierrakos et al. (2013). Study, international background and demographics were drawn from multiple sources and existing surveys at the ANU.

The baseline profile was captured through a student survey administered in compulsory third and fourth year courses in a sequence that meant students could not undertake the survey twice. The specific timing, collection and response rates for the three surveys is given in Table 4.

3.3. Data analysis

Data were collated separately for each survey and not combined, to ensure consistency and that student responses were not double counted. Where relevant, results were tested for statistical significance using T or Fisher Exact Tests.

4. Results

Results are presented corresponding to the research questions.

4.1. Student participation

The overall number of students participating in optional HumEngEdu is shown in Table 5. This is likely an underestimate as complete class lists

Table 4. Data-collection periods and response rates. Response rates are the number of returned surveys from the potential pool undertaking the initiative in the specified time-period, where the potential pool is known from enrolment data.

Survey	Timing and Collection	Responses Valid (N)	Response Rate (%)
HumEng Research Project Pre-Survey	Within first week of starting project, since beginning of 2017	11	Not available
HumEng International Experience Pre-Survey	Once accepted onto programme but before departing, since summer of 2016–17	24	Not available
3rd/4th Year Profile Survey	Week 6–7 of semesters 1 and 2, in 2017	165	64.0 (out of 286)

Table 5. Number of students participating in optional HumEng courses and projects from 2007 to January 2018. Students may be engaged in multiple initiatives.

Initiative	Year Started at the ANU	Total HumEng Students
Research and Design Projects (ENGN4200, BE(R&D), ENGN4221)	2007	135
EWB Summits	2015	64
Engineering for a Humanitarian Context Course	2015	78
Enabled Futures Study Tour	2016	8
Other HumEng Study Abroad Opportunities	n/a	2
Community Based Work Experience or Internships	2013	11

providing specific topics and projects were not available for all research project topics or internship reports.

The number and percentage of HumEng topics students are selecting for later year courses is shown in Table 6. Specific data on number of projects in second year courses was not available as it had not been recorded. This is again likely an underestimation as a relatively narrow definition of HumEng was adopted, where there was an identified target group considered marginalised, vulnerable or disadvantaged. It did not include projects that could have potential applications in humanitarian contexts or general healthcare.

The number of study abroad experiences students have completed from the third/fourth year survey is shown in Table 7.

Financial support used by students undertaking a HumEng international experience is shown in Table 8, drawn from the HumEng international experience survey.

4.2. Student characteristics

Student characteristics were derived from the elements in Table 3 and presented for the four cohorts in Figure 2. HumEng Research Projects refers to Research and Design Projects at the top of Figure 1, while HumEng International experiences are any short-term study abroad experience with a HumEng focus, including EWB Summits and Enabled Futures (also shown in Figure 1.

Current study and demographics for students involved in HumEng initiatives are shown in Table 9 along with the baseline third/fourth year results. As can be seen, there is a higher percentage of females engaged,

Table 6. Number of HumEng projects in courses since the pathway was completed in 2015.

Course	Project Type	Total of All Projects	HumEng Projects	% which are HumEng
ENGN4200 (total)	Individual	326	31	8.6
2015 S1		41	3	7.3
2015 S2		n/a	8	n/a
2016 (total)		143	14	9.8
2017 (total)		142	11	9.2
ENGN4221 2017	Groups of 4–6	41	4	9.8
ENGN3230 Innovation 2017	Groups of 4–6	25	3	12.0

Table 7. Study abroad experiences undertaken (from a total of 57 experiences identified) by 3rd/4th year survey respondents.

Initiative	*N*	%
EWB Summit	15	26.3
Enabled Futures	3	5.3
GlobeX (China)	3	5.3
Overseas Short Course	4	7.0
Exchange	20	35.1
Other	12	21.1

Table 8. Support for students undertaking a HumEng international experience (from 24 responses). # one no response for source of scholarship.

Financial Support	Number (*N*)	Percentage
Scholarship – Any	21	87.5
Scholarship – NCP (of total scholarships)	18	85.7
Scholarship – ANU (of total scholarships)	2	9.5#
OS HELP Used	2	8.3
OS HELP Eligible, not used	15	62.5
OS HELP Not Eligible	6	25.0
Would have still taken part without scholarship (Y/N)	Y = 10	41.7

although not significantly so. Higher rates of engagement were found with students from rural backgrounds. Almost all students engaging are domestic, and hence have significantly higher levels of English as a first language. Building from evidence that many students have an engineer as a close family member, a similar question was asked relating to humanitarian work. However, this appeared to not make any difference.

Table 10 shows student non-study commitments and previous experiences. This shows students engaging with HumEng are both more likely to have worked while studying at university as well undertake unpaid work. They are more likely, in many cases significantly so, to be involved in volunteer or community work and with university organisations, where they are more likely to have had leadership roles, although this last point is not statistically significant.

Responses to questions on students' engineering identity are provided in Table 11. Students involved with HumEng appear more comfortable studying engineering as they exhibit less regret choosing to study engineering than the baseline, although not significantly so. HumEng students appear to attach less importance to being an engineer (in one case significantly so) and identify less with engineers.

Table 9. Study and demographics for students engaged with HumEng initiatives compared to 3rd/4th year overall cohort. * are significant to $p < 0.05$ for both T and Fisher Exact tests.

	All Third/ Fourth Year		HumEng Research Project		HumEng International Experience		HumEng International (from Third/ Fourth Year)	
Characteristic	*N*	%	*N*	%	N	%	*N*	%
Valid Survey Responses	165		11		24		16	
Studying Double Degree (Engineering plus another)	33	20.0	7	63.6	12	50.0	7	43.8
Age Started University (Average Years)	19.1		21.1		19.8		18.3	
Current Age (Average Years)	22.0		25.4		21.9		21.9	
Years at Uni (for current programme average in years)	3.8		4.7		3.7		4.2	
Receiving Degree Scholarship	17	10.3	2	18.2	6	25.0	2	12.5
In Full-Time Study	158	95.8	10	90.9	20	83.3	15	93.8
Female	37	22.4	4	36.4	7	29.2	3	18.8
Domestic Student	94	57.0	**10***	**90.9***	**23***	**95.8***	**15***	**93.8***
English as First Language	84	50.9	9	81.8	**19***	**79.2***	**15***	**93.8***
Know Other Language(s)	90	54.5	7	64.6	8	33.3	4	25.0
Engineer as Close Family Member	69	41.8	3	27.3	9	37.5	7	43.8
Humanitarian Worker as Close Family Member	33	20.0	1	9.1	4	16.7	4	25.0
First Generation in Family to Attend University	24	14.5	1	9.1	6	25.0	2	12.5
Spent Most Time Growing up in Rural Setting	23	13.9	3	27.3	**9***	**37.5***	3	18.8
Identify as Aboriginal or Torres Strait Islander	0	0.0	0	0.0	0	0.0	0	0.0
Supported by the ANU Access and Inclusion	13	7.9	2	18.2	2	12.5	0	0.0

Table 10. Non-study commitments and previous experiences for students engaged with HumEng initiatives compared to the third/fourth year overall cohort. # not asked for all participants, so out of 15 potential students. @ are significant to $p < 0.05$ for Fisher Exact test. * are significant to $p < 0.05$ for both T and Fisher Exact tests.

	All Third/ Fourth Year		HumEng Research Project		HumEng International Experience		HumEng International (from Third/ Fourth Year)	
Experience/ Commitment	*N*	%	*N*	%	*N*	%	*N*	%
Valid Survey Responses	165		11		24		16	
Completed a Gap Year	32	19.4	5	45.5	5	20.8	5	31.3
Involvement in community or volunteer work	98	59.4	9	81.9	19	79.2	**15@**	**93.8**
Age when first took part in community or volunteer work (average in years)	16.9		15.4		16.9		16.7	
ACT based community or volunteer work (% from any involvement)	56	57.1	7	77.8	13	68.2	11	73.3
Previous or current engineering work experience	103	62.4	9	81.8	15	62.5	13	81.3
Previous or current unpaid work (% of total with work)	38	36.9	**6@**	**66.7@**	**8@**	**53.3@**	7	53.8
Undertaken study abroad programme	53	32.1	5	45.5	11	45.8	16	100.0
Age of first study abroad programme (average in years)	19.6		21.0		20.1		20.1	
Worked while at university	112	67.9	9	81.8	14#	93.3#	14	87.5
Highest work commitment (average in hours)	22.0		22.2		24.8		25.2	
Work only or mainly during teaching breaks (% of total with work commitments)	26	23.2	3	33.3	3	21.4	2	14.3
Work is main source of financial support for studies (% of all students)	40	24.2	5	45.5	8#	53.3#	10	62.5
Involved with student or university organisations	92	55.8	8	72.7	**23***	**95.8***	**14***	**87.5***
Highest level of regular involvement (average in hours)	9.5		14.1		11.8		11.1	
Undertaken leadership role (% from those involved)	28	30.4	5	62.5	11	47.8	7	50.0
Responsible for regular care of a family member	18	10.9	1	9.1	1	6.7	2	12.5

Table 11. Average student responses for engineering identity rated on a scale of 1 (strongly disagree) to 5 (strongly agree). * are significant to $p < 0.05$ for both T and Fisher Exact tests.

Statement	All Third/ Fourth Year	HumEng Research Project	HumEng International Experience	HumEng International (from Third/ Fourth Year)
In general, being an engineer is an important part of my self-image	3.42	2.73	3.60	3.06
I will be happy to be an engineer	3.88	3.91	4.00	3.75
Overall, being an engineer has very little to do with how I feel about myself	2.81	3.18	3.00	3.38
I often regret that I chose to be an engineer	2.19	1.64	1.80	2.03
Being an engineer is important to how I feel about myself	3.24	**2.36***	2.60	3.00
I identify with engineers	3.49	3.18	3.00	3.31

Table 12 shows students' attitudes to study. Broadly, there is very little difference between HumEng students and the baseline, although students involved in international experiences have greater levels of frustration, although the causes for this are not clear.

Table 13 shows student views of the importance of different areas of engineering practice. Those involved with HumEng tend to rank professional skills and ethical practice more highly than the baseline group.

Table 12. Average ratings for attitudes to engineering classes, rated on a scale of 1 (strongly disagree) to 5 (strongly agree). @ significant to $p < 0.05$ for Fisher Exact Test.

In my engineering classes I feel	All Third/ Fourth Year	HumEng Research Project	HumEng International Experience	HumEng International (from Third/ Fourth)
Frustrated	3.06	2.73	3.60	**3.75**@
Angry	2.14	1.91	2.00	2.19
Overworked	3.53	3.09	3.20	3.69
Happy	3.37	3.64	3.80	3.38
Enthusiastic	3.39	3.36	3.60	3.28
Insecure	2.52	2.09	2.20	2.50
Fulfilled	3.25	3.18	3.20	3.03
Challenged	4.00	4.00	4.00	4.09
Motivated	3.36	3.45	3.40	3.09

4.3. Student motivations

Table 14 provides motivations for given 'application areas' (based on those identified in Kinash et al. 2015; Litchfield and Javernick-Will 2016). The career motivations of students involved in HumEng experiences can be clearly seen.

Table 15 provides motivations for undertaking HumEng initiatives from the two HumEng surveys only. As expected, the highest motivations for research is just that, similarly travel is high for international experiences, whereas it is not common for research projects.

5. Discussion

5.1. Student engagement

The overall level of student participation in HumEng is approximately 10% of third/fourth year students. This is the percentage of students selecting a HumEng project topic for a group or individual assignment (Table 6) as well as the percentage who have been on a HumEng study abroad experience (Table 7). The role of NCP funding is significant, as more than half of the students would not have taken part if a scholarship was not available (Table 8). Access to international experiences has in turned increased involvement in final year projects since 2016 (Table 6).

Comparing the characteristics of students engaging in HumEng to the overall 3rd/4th year cohort, differences were found (Table 9). Students engaging with HumEng are almost entirely domestic, over 90% compared to a base of 57%. For international experiences, this could be related to conditions for Government Scholarships which are limited to domestic students, although the trend is the same for research experiences. However, within the domestic cohort there is a higher level of diversity with generally more females and students from rural backgrounds. Similar results have been reported in the United States (Litchfield, Javernick-Will, and Maul 2016).

Table 13. Views of importance of different areas to engineering practice, ranked on a scale of 1 (NI – not important) to 4 (VI – very important). # limited data collected, not tested for significance. ^ significant for *T*. Test with $p < 0.05$.

Area	All Third/ Fourth Year	HumEng Research Project	HumEng International Experience#	HumEng International (from Third/ Fourth)
Fundamental knowledge (such as maths and science)	3.38	3.27	3.20	3.25
Business skills (project management, entrepreneurship)	2.92	3.00	3.00	2.94
Research skills (conducting research, contemporary issues)	3.15	2.91	3.00	3.06
Interdisciplinary knowledge (from a non-engineering field or discipline)	2.92	2.82	3.00	3.00
Engineering Discipline knowledge (in my major area)	3.39	3.18	3.40	3.31
Professional skills (such as communication or teamwork)	3.66	**3.91^**	3.80	**3.88^**
Ethical practice (integrity, social responsibility, sustainable development)	3.28	**3.82^**	3.40	3.44
Technical skills (design process, simulation, modelling, …)	3.38	3.18	3.60	**3.00^**
Systems engineering (defining scope and problem, systems boundaries, considering lifecycles)	3.09	3.36	3.60	3.00

Table 14. Average student preferences for application areas of engineering upon graduation. Responses were *1 – None* to *4 – Strong Interest*. Average score out of 4 and rank order for each cohort are provided. The top three for each cohort highlighted yellow, grey and brown in order. ^ significant for *T*. Test for $p < 0.05$.

Application Area	All Third/ Fourth Year		HumEng Research Project		HumEng International Experience		HumEng International (from Third/ Fourth Year)	
	Rank	/4	Rank	/4	Rank	/4	Rank	/4
Multi-national corporations	1	3.01	2	3.18	3	2.71	4	2.75
Entrepreneurship (start-up companies) or own business	4	2.63	6	2.36	6	2.58	6	2.38
Government or public policy	9	2.20	8	2.09	9	2.08	9	2.06
Competitive sports	11	1.79	11	1.64	11	1.92	11	1.88
Humanitarian responses, or community, not-for-profit or social organisations	8	2.24	**1^**	**3.36^**	**1^**	**3.13^**	**1^**	**2.88^**
Research and development (R&D)	5	2.62	7	2.36	4	2.65	7	2.31
Defence/Defence Industry	7	2.38	9	2.09	10	2.08	10	2.06
Engineering manufacturers or industrial organisations	2	2.93	5	2.64	5	2.63	5	2.69
Consultancies	6	2.5	4	2.73	8	2.46	2	2.81
Education or training	10	2.05	10	2.09	**7^**	**2.5^**	8	2.25
Technology or project management	3	2.92	3	3.09	2	2.79	3	2.81

Table 15. Top motivations for students to engage with an optional HumEng experience. Responses range from 1 (strongly disagree) to 5 (strongly agree). The top three for each cohort highlighted yellow, grey and brown in order (22 items in total).

	HumEng Research Project		HumEng International Experience	
Motivation	Rank	/5	Rank	/5
For a research project	1	3.64	22	1.52
Application of engineering	2	3.32	2	3.58
Use my engineering to help	3	3.27	4	3.43
To count as course credit or requirement	4	3.18	16	2.33
To challenge myself	5	3.17	6	3.26
To work on complex problems	6	3.09	5	3.38
Interested in humanitarian engineering	10	2.73	1	3.61
Interested in travelling	13	2.55	3	3.43

Students engaged with HumEng are having a wider range of experiences (Table 10). They are more likely to have had a gap-year (up to 46% compared to 19%), involvement with community or volunteer work (80% compared to 60%), more likely to have engineering work experience and more likely to have involvement with student or university organisations (70% or more compared to 56%). The impact of these experiences may be seen in students' attitudes to engineering (Table 13). They are more likely to consider professional skills and ethical practice important for engineering practice, and in some cases have less emphasis on technical skills. In a similar result, Bielefeldt and Canney (2014) found students with higher levels of SL participation at school had higher than average social responsibility. Students broadly identify with, and are happy being, engineers (Table 11), apparently more frustrated studying engineering, but possibly less insecure (Table 12).

These results paint a picture of confident student engineers with a broad view of engineering, undertaking as many experiences as possible while studying. This aligns with a T-shaped view of graduates generally as described in Kinash et al. (2015). Here, discipline depth (the stem of the T) is combined with professional skills (the top of the T) to ensure both engineering and generic graduate attributes are achieved.

5.2. Student motivations

Students appear to be motivated by an interest in applying their engineering work in the *real world* (Table 15). As part of that, creating positive impact or *helping* is an additional motivation. Of the top six motivations, four are common to both groups. No statistically significant differences were found across gender for motivations, mostly due to the sample size. All three survey cohorts involved with HumEngEdu in the pathway had humanitarian responses, or community, not-for-profit or social organisations as the highest ranked career application (Table 14). The only other statistically significant difference was for international experience students ranking education or training more highly. This highlights the need to consider expectations for careers and employment. As identified by Litchfield and Javernick-Will (2016), career and professional aspirations may not match the opportunities available and unmet motivations can be a concern, particularly for females. Combined with students' being potentially less likely to identify with being engineers (Table 11), this could suggest graduates engaged with HumEng may move out of engineering roles into other careers if their aspirations are not satisfied (as suggested by Litchfield and Javernick-Will 2016).

5.3. Limitations, recommendations and further work

Some limitations are present in the data collection and analysis. The analysis would benefit from larger sample sizes to give greater confidence in comparisons made and conclusions drawn. Data will continued to be collected throughout 2018/19. It is also not possible to identify every student engaged with HumEng, and some of the engagements are underestimated.

At the ANU, forms of recognition are being examined for the pathway. One option is the US National Academy of Engineering (NAE) Grand Challenge Scholars Program (GCSP). This would provide an additional certificate for efforts across study, co- and extra-curricular activities. A four-course minor combining courses from engineering and other fields including social science, development studies and environmental management, is being planned.

At a national level, work is underway to collect data from multiple universities involved with HumEngEdu. This will evaluate programmes and impact across Australia, allowing for comparison and identification of best practice. There is a need to track graduates to see if they work in HumEng or even remain in engineering. Data and previous research indicates they could leave the field, driven by career aspirations that could remain unmet if opportunities are lacking within HumEng. National programmes could be considered to support students looking for careers in the area, to provide work experience and connect graduates to opportunities.

6. Conclusion

By incorporating a HumEngEdu pathway within the core of an engineering programme, it was found approximately 10% of students engaged with optional experiences or selected project topics in the field. This included students undertaking short-term international experiences (9.7%), final year individual or group research and design projects (8.7%), and project topics in third year (12%).

Through a series of surveys, it was found students undertaking these experiences were more likely to be female, domestic and from rural backgrounds when compared to the overall engineering cohort. Students involved with HumEngEdu undertook a wider range of experiences and extra-curricular activities both in school and at university. They were more likely, in many cases significantly so, to value professional skills and ethical practice highly as part of the competencies required for engineering. This has potential lessons for engineering education broadly, and is being explored through the qualitative aspects of the overall study.

Students undertaking HumEng experiences were found to be motivated through both a desire to help or have impact with their engineering and to see or experience the application of their engineering. Students involved with HumEng experiences were likely to place humanitarian or development work as their highest preference from a set of 11 career application areas. Further research will explore if these aspirations were already present or developed though their HumEng experiences.

Broadly, these findings, the first such study of HumEngEdu in Australia, are similar to research in other countries. They highlight that HumEngEdu attracts a more diverse cohort of domestic students. Students engaging with HumEngEdu fit the contemporary T-shaped graduate, with their discipline depth supplemented by a wide range of co- and extra-curricular activities and a greater appreciation of professional practice. This in turn may contribute to greater employability in general. However, concerns are apparent to ensure career expectations are met, with evidence indicating graduates with interests in the area could leave the field. However, it is clear that the growth of HumEngEdu in Australia is contributing to a more diverse and experienced engineering profession and the benefits this brings.

Acknowledgements

The authors wish to thank the community partners and individuals who provided project opportunities, support and supervision to students during their studies. We thank all the students who have undertaken surveys.

Disclosure statement

The first author was a previous EWB-A paid staff member before commencing the research outlined here.

Funding

The development of the Engineering for a Humanitarian Context course was supported by an Australian Government Office for Learning and Teaching grant. The research work has been supported by an Australian Government PhD scholarship;Department of Industry, Innovation, Science, Research and Tertiary Education, Australian Government [Research Training Program]; Office for Learning and Teaching [SD14-3802].

Notes on contributors

Jeremy Smith is a Lecturer in the Research School of Engineering at the Australian National University. He is a Fellow of Engineers Australia and a Senior Fellow of the Higher Education Academy and in 2017 received an Award for Teaching Excellence from the Australian Awards for University Teaching education.

Andrea Mazzurco is a Lecturer of Engineering Education in the new Engineering Practice Academy in the Faculty of Science, Engineering, and Technology at Swinburne University of Technology. Andrea's primary research interests focus on global engineering competency, humanitarian engineering, and moral development of engineers and engineering students.

Paul Compston is a Professor in the Research School of Engineering at the Australian National University and Deputy Director for the Australian Research Council Training Centre for Automated Manufacture of Advanced Composites. Paul is a Fellow of Engineers Australia and a Senior Fellow of the Higher Education Academy.

ORCID

Jeremy Smith http://orcid.org/0000-0002-3991-4059

References

Berg, D. R., T. Lee, and E. A. Buchana. 2016. "A Methodology for Exploring, Documenting, and Improving Humanitarian Service Learning in the University." *Journal of Humanitarian Engineering*, 4(1).

Bielefeldt, A., K. Paterson, C. Swan, O. Pierrakos, D. O. Kazmer, and A. Soisson 2013. "Spectra of Learning through Service Programs." *Presented at the 120th ASEE Annual Conference and Exposition*, Atlanta.

Bielefeldt, A. R., and N. Canney. 2014. "Impacts of Service-Learning on the Professional Social Responsibility Attitudes of Engineering Students." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* 9 (2): 47–63. doi:10.24908/ijsle.v9i2.5449.

Bratton, M. 2014. "Global TIES: Ten Years of Engineering for Humanity." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* 205–221. doi:10.24908/ijsle.v0i0.5549.

Duffy, J., C. Barry, L. Barrington, and M. Heredia. 2009. "Service-Learning in Engineering Science Courses: Does It Work?" In *American Society for Engineering Education Annual Conference Proceedings*, Austin, TX, AC 2009-2160, pp. 1-24.

Greet, N. 2014. "Building a Humanitarian Engineering Network–A Collaborative Challenge." *In Humanitarian Innovation Conference Proceedings*, July 19-20, Univeristy of Oxford, pp. 19–20.

Huff, J., C. B. Zoltowski, W. C. Oakes, and R. Adams. 2013. "Making Sense of Design. A Thematic Analysis of Alumni Perspectives." Presented at the 120th ASEE Annual Conference and Exposition, Atlanta.

Johnson, F., S. Foster, C. Frankel, S. Johnson, S. Moore, R. Stuetz, and J. Thomas 2017. "Making a Difference: Creating Opportunities for Undergraduate Students to Contribute to Humanitarian Engineering Projects." 28th Annual Conference of the Australasian Association for Engineering Education (AAEE1017) Order of Proceedings, Manly.

Kinash, S., L. Crane, M. Judd, C. Knight, and D. Dowling July 2015 "What Students and Graduates Need to Know about Graduate Employability: Lessons from National OLT Research." Higher Education Research and Development Society of Australasia Conference, Melbourne.

Leydens, J. A., and J. C. Lucena. 2014. "Social Justice: A Missing, Unelaborated Dimension in Humanitarian Engineering and Learning through Service." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* 9 (2): 1–28. doi:10.24908/ijsle.v9i2.5447.

Litchfield, K., and A. Javernick-Will. 2016. "Socially Engaged Engineers' Career Interests and Experiences: A Miner's Canary." *Journal of Professional Issues in Engineering Education and Practice* 143(1): pp. 1-10.

Litchfield, K., A. Javernick-Will, and A. Maul. 2016. "Technical and Professional Skills of Engineers Involved and Not Involved in Engineering Service: Technical and Professional Skills of Engineers in Engineering Service." *Journal of Engineering Education* 105 (1): 70–92. doi:10.1002/jee.v105.1.

Moskal, B. M., C. K. Skokan, D. R. Munoz, and J. Gosink. 2008. "Humanitarian Engineering: Global Impacts and Sustainability of a Curricular Effort." *International Journal of Engineering Education* 24 (1): 162–174.

Nieusma, D., and D. Riley. 2010. "Designs on Development: Engineering, Globalization, and Social Justice." *Engineering Studies* 2 (1): 29–59. doi:10.1080/19378621003604748.

Passino, K. M. 2009. "Educating the Humanitarian Engineer." *Science and Engineering Ethics* 15 (4): 577–600. doi:10.1007/s11948-009-9184-8.

Pierrakos, O., R. Nagel, E. Pappas, J. Nagel, T. Moran, E. Barrella, and M. Panizo. 2013. "A Mixed-Methods Study of Cognitive and Affective Learning during A Sophomore Design Problem-Based Service Learning Experience." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* 1–28. doi:10.24908/ijsle.v0i0.5145.

Smith, J., B. Anderson, N. Brown, A. Colley, A. Stoakley, and J. Turner 2017. "The Rise of Humanitarian Engineering Education in Australasia." 28th Annual Conference of the Australasian Association for Engineering Education (AAEE1017) Order of Proceedings, Manly.

Thomas, J., P. Matous, P. Café, and A. El-Zein 2017. "Lessons Learned from the Design and Delivery of a New Major in Humanitarian Engineering." 28th Annual Conference of the Australasian Association for Engineering Education (AAEE1017) Order of Proceedings, Manly.

Turner, J., N. Brown, and J. Smith 2015. "Humanitarian Engineering: What Does It All Mean?" 26th Annual Conference of the Australasian Association for Engineering Education (AAEE1015) Order of Proceedings, Geelong.

Vandersteen, J. D. J., C. Baillie, and K. Hall. 2009. "International Humanitarian Engineering." *IEEE Technology and Society Magazine* 28 (4): 32–41. doi:10.1109/MTS.2009.934998.

Wilson, D., D. Jones, M. J. Kim, C. Allendoerfer, R. Bates, J. Crawford, and N. Veilleux. 2014. "The Link between Cocurricular Activities and Academic Engagement in Engineering Education: Cocurricular and Engagement Activities and Academic Engagement." *Journal of Engineering Education* 103 (4): 625–651. doi:10.1002/jee.20057.

Chapter 7: Impacts of a Humanitarian Engineering Education Pathway on Student Learning and Graduate Outcomes

Foreword

Following the previous Chapter's investigation of student engagement, this Chapter provides a journal article exploring the outcomes of the engagement with the Humanitarian Engineering (HumEng) pathway at the ANU. It focuses on the third and final research question for the study, investigating outcomes for students from HumEng education. Due to the exploratory nature of the research, opportunities were available for a range of outcomes to emerge, although the research focused on the students only, not external partners or organisations.

As for Chapter 6, multiple data sources are used to identify potential outcomes. This includes surveys from the same courses and initiatives as the previous Chapter, although generally focusing on post-experience surveys to identify the outcomes from engagement. The main focus of the data collection was interviews with graduates, which is the predominant data collection form for the study as a whole. Graduates were invited to take part in an interview if they had completed two or more optional HumEng experiences and were within three months of graduation or completion of their program requirements, whichever came first. Using a semi-structured approach and question prompts, the interviews allowed students to identify outcomes from their studies and engagement with HumEng education.

The Chapter briefly describes the HumEng pathway including its main initiatives and how this can be integrated into a student's studies. Previous mixed-methods studies from similar programs are critiqued, which helped shaped the study design and data collection methods. Results from surveys and enrolment data are provided for specific HumEng initiatives in addition to the pathways described by graduates during interviews. This contributed to the identification of three distinct pathways linked to the types of engagement and experiences completed. Finally, seven outcome themes are presented based on the analysis from both qualitative and quantitative data. Insights are provided in the discussion for key areas that were identified as significant, specifically demographics, pathways, and curriculum structure and development. The design of a new four-course *Minor in Humanitarian Engineering* commencing in 2019 at the ANU was based on the findings is described here.

International Journal for Service Learning in Engineering,
Humanitarian Engineering and Social Entrepreneurship
Vol. 14, No. 1, pp. 1-20, Spring 2019
ISSN 1555-9033

Impacts of a humanitarian engineering education pathway on student learning and graduate outcomes

Jeremy Smith
Lecturer, Research School of Engineering
Australian National University
ACT, Canberra, Australia
jeremy.smith@anu.edu.au

Jennifer Turner
Engineer in Residence, Engineering Practice Academy
Swinburne University of Technology
Melbourne, Victoria, Australia
jturner@swin.edu.au

Paul Compston
Professor, Research School of Engineering
Australian National University
ACT, Canberra, Australia
paul.compston@anu.edu.au

Abstract - **This study explores the impact on students from engagement with a humanitarian engineering pathway embedded in the core of an undergraduate engineering degree. The pathway provides multiple engagements with humanitarian engineering including assignment topics, study abroad experiences and service-learning projects. A mixed-methods study over 18 months collected survey data from education initiatives concurrently with interviews with graduates at completion of their studies, to identify outcomes from student engagement. A set of seven outcome themes were identified including additional motivations for study, the development of professional skills, and an enhanced perception of employability. The research demonstrates the contribution of humanitarian engineering to the development of contemporary engineers as well as to support greater diversity and cultural change in engineering. However, challenges were identified particularly for work experience and career opportunities. The research proposes future work evaluating outcomes from multiple universities and graduates further in their careers, to develop a more complete picture of the impacts of humanitarian engineering.**

Index Terms - humanitarian engineering, employability, diversity, service-learning.

INTRODUCTION

Humanitarian Engineering (HumEng) has proven popular with students and institutions in developed countries, with established education initiatives available in the USA[1,2,3], Canada[4] and the UK[5], and emerging programs in Australia and New Zealand[6,7,8]. In Australasia, HumEng seeks to apply engineering to disadvantaged, marginalised and vulnerable individuals and communities to improve quality of life for both domestic and overseas short- and long-term humanitarian action and development contexts[7,9].

However, in preparing engineers for such roles there are no agreed competencies for HumEng practice. Previous work has highlighted the need for topics including cross-cultural collaboration, multi-disciplinary engagement, global competencies, ethical practice and social responsibility or justice[2,4,10,11]. Recent studies have demonstrated how HumEng can foster student learning in these areas, particularly social responsibility[12], professional skills[1,3,13], and cross-cultural competency[1]. To achieve these, education programs often incorporate study abroad and project-based service-learning curriculum, where student learning from engagement with external community groups is recognised[1,3]. Previous studies have also highlighted requirements and challenges for the design, delivery and support of programs, including cost, staff commitments, and relationship management[2,6,8].

The countries with the greatest presence of HumEng programs are governed and accredited in similar ways through professional associations and competency frameworks, and support mobility through international agreements. However, they have different priorities and historical contexts for humanitarian action and development, which in turn impact the design and delivery of HumEng programs. To contribute to the research in HumEng education, this work examines one of the early programs in Australasia. It investigates outcomes for students from engagements with HumEng education during their engineering undergraduate studies at a single institution. The aim is to identify any skills and knowledge acquired from HumEng education in addition to outcomes for students' overall studies and engineering practice.

METHODOLOGY

Humanitarian engineering pathway

At the Australian National University (ANU), a HumEng education pathway was established within the bachelors engineering program. The degree is accredited by Engineers Australia (EA), the peak professional body, and is recognised through international agreements for mobility including the Washington Accord. The degree has a compulsory systems engineering core through all four years, with students selecting a discipline major in second year. It was the natural alignment between systems and humanitarian engineering[14] that provided an initial motivation for the pathway. It built on the accepted understanding of HumEng in Australasia which incorporates domestic and overseas short-term humanitarian action and long-term community development[7,9] although incorporated ideas and curriculum from existing programs internationally[1,2,3,4]. However, the pathway was specific for Australia's unique humanitarian and development context, which is embedded in the country's location, geo-political influences, history, and domestic challenges and vulnerabilities.

The pathway incorporated programs delivered by Engineers Without Borders Australia (EWB), specifically the EWB Challenge in first year, the two-week immersive study abroad EWB Humanitarian Design Summit (EWB Summit) in middle to later years, and the EWB Undergraduate Research Program in the final year[7]. Costs for the EWB Challenge and EWB Undergraduate Research program are borne by the institution through a formal partnership, while involvement in EWB Summits is covered by students, although scholarships are available for eligible students which provide approximately 60-70% of the cost[7]. EWB programs were

International Journal for Service Learning in Engineering,
Humanitarian Engineering and Social Entrepreneurship
Vol. 14, No. 1, pp. 1-20, Spring 2019
ISSN 1555-9033

complemented by project-based and service-learning opportunities in core second, third and fourth year courses where students could elect to undertake an assignment topic or entire project in HumEng. A dedicated elective course, *Engineering for a Humanitarian Context* (EfaHC), was developed which could incorporate short-term study abroad experiences such as EWB Summits[15]. Combined, these initiatives provided a semi-structured pathway for students interested in HumEng with experiences in each of their year levels (see Table 1 for course details). Students could further integrate extra-curricular activities including involvement with school outreach, student clubs and societies, and volunteer work experience or internships with community-based groups and social enterprises. The pathway was developed from 2007 and was fully in-place by 2015.

TABLE 1

COURSES CONTRIBUTING TO THE HUMANITARIAN ENGINEERING PATHWAY

Course	Delivery Year and Session (S is Semester)	Opportunity, Projects or Content
Discovering Engineering	Year 1, S1	EWB Challenge, compulsory for all students.
Systems Design and Systems Analysis	Year 2, S1 Year 2, S2	Domestic projects focusing on access, inclusion and disability, and follow-up EWB Challenge projects.
Engineering Innovation	Year 3, S2	Student generated ideas for social enterprises.
Work Experience	Any	Work experience or internships with community-based organisations or social enterprises.
Engineering for a Humanitarian Context (EfaHC)	Year 3 or 4, summer or winter	Full elective course (6-unit) delivered in intensive mode incorporating study abroad experiences, with pre- and post-travel workshops and assessment.
Individual Research Project	Year 4, S1 and S2	Service-learning projects with external partners or applications of research to development or humanitarian contexts, running over a full academic year.
Systems Engineering Project	Year 4, S1 or S2	Group design and engineering service-learning projects with external partners (group capstone project).

Previous Studies

As there are no agreed competencies in the area, existing work on HumEng and its common curriculum approaches was used to both inform the design of the pathway and develop a research strategy to investigate student outcomes. Mixed-methods studies were common and found to be the most appropriate evaluation approach, allowing inclusion of a range of data sources and collection methods. This was particularly beneficial for new programs as was the case here, to enable an exploration of student outcomes without assumptions of potential benefits. For example, an embedded, sequential, qualitative rich mixed-methods approach was used to explore the impact on views of design in engineering practice from involvement in an engineering community service-learning program (EPICS) in the US[16]. This drew on a survey of 523 participants and interviewed 27 alumni identified using maximum variation sampling. Interview transcripts were analysed using an open coding approach to identify codes which were then organised into themes capturing how design was understood by participants. This uncovered three main ways of articulating design; *design boundaries*, *lifecycles*, and *situated knowledge*.

The use of project-based and service-learning curriculum to enhance students' abilities to integrate non-technical elements into community-based design experiences was investigated[11]. This used a case study approach utilising mixed-methods data collection from multiple sources including pre- and post- interviews, reflections, and assessment surveys linked to specific later year coursework. Five students were interviewed, while between 15 and 25 participants were involved with other data collection methods. The use of a transdisciplinary knowledge production model was proposed to further student abilities based on the findings of an increase in student knowledge of non-technical dimensions in design. Both[11,16] used a separate researcher to conduct interviews to avoid potential bias from the researcher and students having worked together.

The impacts of problem-based service-learning on cognitive and affective learning outcomes and gains achieved by second year engineering students has been explored[3]. A concurrent triangulation study design was adopted with a survey using quantitative and qualitative items to cover the breath of competencies and knowledge in technical and professional engineering practice domains. Surveys were completed by 72 students in the first half of second year and 45 in the second half, giving a total of 117 responses. Quantitative and qualitative data was triangulated to provide greater confidence in the outcomes. It was found students were challenged by the complexity of service-learning but gained knowledge and valued the experience, although appropriate scaffolding was recommended for second year students.

Motivations and learning outcomes of socially engaged engineers, both students and graduates, have been explored using a sequential mixed-methods design[13,17]. Exploratory interviews and focus groups with 165 participants identified key themes and elements related to personality traits, motivations and experiences. These were used to develop a survey which received over 2,500 responses from engineering students and professionals. Outcomes found similar levels of technical skills from participants but greater levels of professional skill development for those involved in service-learning initiatives. Participants with engineering service experience were also found to emphasise social, cultural, gender, and economic factors in complex design, a similar finding to[11].

Self-identified student outcomes from a three-week immersive international HumEng experience have been investigated[1]. These were drawn from 106 student reflections at the end of their trip using grounded theory and criteria including frequency and context to identify categories. Six broad categories were identified, *resourcefulness and innovation*, *teamwork*, *intercultural competency*, *professionalism*, *understanding theory vs practice* and *personal development*, each of which had further sub-categories. This demonstrates the potential of student self-reporting to identify perceived outcomes.

Beyond engineering, multiple data sources including transcripts, resumes, and award applications, supported by student focus groups, were used to identify student created pathways for engagement in diverse democracy in the absence of any formal university program[18]. By coding and analysing the data, four distinct pathways were identified which could contribute to learning in the area. This is similar to the HumEng pathway constructed here, which is not part of a formal award structure and consists of curricular and extra-curricular activities selected by students.

Research Design

Building from the studies described above, the research here employed a concurrent nested strategy[19] to investigate the outcomes for students resulting from multiple engagements with the HumEng pathway. Quantitative and qualitative data were simultaneously collected from two main sources, with an emphasis on rich qualitative data. Quantitative survey data was collected after individual courses or experiences, specifically the EfaHC course, study abroad experiences, and final year projects. Qualitative data on experiences across multiple HumEng engagements was collected from interviews with graduates within three months of graduation or completion of their degree requirements, which ever came first. Participants were not compensated for their involvement (as is the norm in Australia). Triangulation across the multiple data sources was used to support analysis and findings, similar to[3]. All aspects of the research were approved by the university's Human Ethics Committee.

Data Collection

Quantitative surveys drew upon existing research which highlighted potential benefits in areas including professional skills[13], social responsibility[12], and applications of engineering[11]. These were captured in three sets of questions. First, 15 items on a scale of one (none) to four (significant) were used for learning gains (see Table 4). Second, changes in employment preferences were measured in 13 areas (see Table 5), based on Australian work on employability[20], scored from one (less likely) to five (more likely). Finally, a series of 12 statements (see Table 6) were ranked from one (strongly disagree) to five (strongly agree scale). These built from a study exploring threshold concepts in the EfaHC course at the ANU which identified taking account of social factors, cross-cultural competency, and communication as learning gains made by students[15]. Study and demographic data was collected with a particular emphasis on indicators of diversity in Australia. Early surveys contained a question on "cultural identity" which did not prove useful in an Australian context, with responses including terms such as "good". Rather English as a first language and identification as Australian Aboriginal or Torres Strait Islander were used to provide an indication of cultural diversity.

Similar demographic data was collected through a survey of all third and fourth year engineering students at the ANU to provide a baseline for comparison to those engaged in HumEng. The baseline captured all students in the engineering bachelors program, including those involved in HumEng experiences, to give the most complete description of the overall engineering student cohort. Many of the overall engineering student cohort would have undertaken the EWB Challenge in first year, which was a compulsory component of the course it was embedded in, although others will have entered the degree program in later years and not have been exposed to any HumEng experiences (see[21] for details of the quantitative surveys and findings).

Semi-structured interviews were conducted with students who had multiple engagements with HumEng. Participants were identified through a targeted sampling strategy with the criteria of two or more optional HumEng experiences. This excluded the EWB Challenge in first year, as it is compulsory. If a student met the sampling criteria, they could have potentially been participants in the baseline survey and surveys linked to specific HumEng experiences, due to the anonymous nature of the surveys. Course and project lists were used to identify potential students, who were invited to participate in an interview within three months of meeting their course requirements or graduation. This was to focus on experiences from their studies without potential impact or changes resulting from professional practice[13]. Interviews were 30-60mins using the question prompts in the appendix, and were recorded and transcribed, with participants electing if they wished for quotes to be attributed anonymously, through a pseudonym, or not used at all. Interviews were conducted by the first author, who had delivered many of the experiences in the pathway, as resources were not available to engage an independent researcher for interviews. To provide confidence and identify potential differences due to bias (as suggested in[11,16]), the anonymous surveys provided an opportunity for participants to provide insights they may not have been comfortable presenting in an interview.

RESULTS

Participants

Over 18 months, 26 potential participants were invited to take part in an interview, of which 21 accepted. Over the same period a survey was conducted after a short-term (two-week) HumEng study abroad experience with 26 responses received from 44 participants. Table 2 provides key demographics of the participants, alongside the comparable baseline for the overall 3rd/4th year cohort. Participant enrolment is shown in Table 8 in the appendix, which shows the variation in majors and double degrees, with students involved with HumEng more likely to be undertaking double degrees compared to the baseline (38-52% for HumEng experiences versus 20% overall).

TABLE 2

DEMOGRAPHICS OF INTERVIEW AND SURVEY PARTICIPANTS AND A COMPARISON 3RD/4TH YEAR BASELINE (F IS FEMALE, M IS MALE, OI IS OTHER OR INTERSEX).

Demographic	Interview	Survey	Baseline
Participants (N)	21	26	165
Response Rate (%)	81	59	64
Domestic Student (%)	95	92	57
Average Age (Years)	23 ⅓	22	22
Gender (F/M/OI) (%)	43/57/0	50/50/0	22/76/2
English as First Language (%)	95	81	51
First Generation in Family to attend University (%)	0	15	15
Australian Aboriginal or Torres Strait Islander (%)	0	0	0
Urban Background (%)	86	73	82

Interviews

Transcripts were analysed using an open coding approach[16] to identify codes leading to emergent themes relating specifically to outcomes students identified from their engagement with HumEng while an undergraduate student. Theme descriptions and sample quotes were captured in a code book by the first author and discussed and critiqued by the other authors. A full list of interviewees in given in Table 9 in the appendix. Table 3 shows the initiatives each student engaged with from the pathway from Table 1.

TABLE 3

HUMENG INITIATIVES ENGAGED IN BY INTERVIEW PARTICIPANTS (N=21).

Initiative	Number	%
EWB Challenge (in Discovering Engineering)	20	95
Final Year Project (Individual or Team)	18	86
Short-Term Study Abroad Experience	16	76
EfaHC Elective Course	15	71
Selected Assignment Topics in Compulsory Core Courses	8	38
Involved with Extra-Curricular Society (for example EWB-Australia)	7	33
Undertook Non-engineering Cross-discipline Courses	5	24
Completed Overseas Research	3	14
Undertook Work Experience	2	10

Surveys

Responses following involvement with an immersive short-term international HumEng experience for each of the three sets of questions outlined in the Data Collection section are shown in Tables 4 to 6.

TABLE 4

ORDERED RESPONSES TO LEARNING GAINS FROM AN INTERNATIONAL HUMENG EXPERIENCE, 1 IS *NONE*, 4 IS *SIGNIFICANT* (N=26).

Learning Gain	4	3	2	1	% 4
Cross-cultural awareness	22	3	0	1	85
Engaging with users or stakeholders	21	4	1	0	81
Ability to work internationally	21	4	1	0	81
Ability to incorporate social factors into engineering	19	4	1	1	76
Communication skills	18	8	0	0	69
Application of engineering to the real-world	17	8	1	0	65
Adaptability	14	6	5	0	56
To the systems engineering core	13	7	5	0	52
Creativity	12	13	1	0	46
Teamwork skills	12	10	4	0	46
Ability to work on complex problems	11	12	3	0	42
Incorporating sustainability into engineering	11	12	3	0	42
Ethical practice	11	12	2	0	44
Engineering design	11	10	4	0	44
To my discipline major	3	1	12	9	12

TABLE 5

ORDERED RESPONSES TO CHANGES IN CAREER MOTIVATIONS (BASED ON[20]) AFTER INVOLVEMENT IN AN INTERNATIONAL HUMENG EXPERIENCE, 1 IS *LESS LIKELY 3 IS NEUTRAL,* 5 IS *MORE LIKELY* (N=26).

Application Area	% 5,4	% 3	% 2,1
Humanitarian responses, or community, not-for-profit or social organisations	92	8	0
Education or training	65	27	8
Technology or project management	58	38	4
Entrepreneurship (start-up companies) or own business	54	31	15
Multi-national corporations	54	35	12
Research and development (R&D)	35	50	15
Engineering manufacturers or industrial organisations	35	46	19
Government or public policy	27	50	23
Consultancies	19	65	15
Competitive sports	0	69	31
Defence / Defence Industry	0	73	27

TABLE 6

ORDERED RESPONSES TO OUTCOMES FROM INVOLVEMENT IN AN INTERNATIONAL HUMENG EXPERIENCE, FROM 1 *STRONGLY DISAGREE* TO 5 *STRONGLY AGREE* (N=26 WITH ONE NO RESPONSE).

Statement	% 5,4	% 3	% 2,1
I learnt about the country I was visiting	100	0	0
I made new friends	100	0	0
This was relevant for my current studies	96	4	0
I learnt about my role as an engineer	96	4	0
I used or applied my engineering skills or knowledge	92	0	8
I learnt new engineering skills and knowledge	92	8	0
I can better connect my studies to the application of engineering knowledge	80	20	0
I had a sense of individual achievement	80	20	0
I am more motivated to complete my studies	72	24	4
I am more motivated to be an engineer	68	32	0
I am more likely to find employment	68	28	4
I made a positive contribution to the country I was visiting	56	40	4
I was able to communicate with everyone I met	56	32	12
My presence had a negative impact on the country	0	12	88

Engagement Outcomes

The analysis of interview transcripts was combined with findings from surveys to identify perceived outcomes for students from their HumEng engagement. Seven outcome themes were identified.

Outcome 1 - Employability

Student perceptions of enhanced employability for a range of graduate and engineering roles was clear from interviewees. For some this was additional experiences on a CV or discussion points in job interviews such as Fred "Yeah well I was more employable, […], because pretty much all the interviews where I talked about the humanitarian stuff, I got offers from all of them." and "every single interview that I went to they were really impressed with the [EWB] design summit" from Janet. Others reported feeling more qualified for a position such as Dalia "I think how it makes me more employable is that it has changed me as a person and how I think and how I approach problems. I think on that level, kind of the intrinsic changes that these experiences have had makes me a more employable person, not necessarily seeing these things on a resume."

Outcome 2 - Tools, Processes and Skills

A number of specific tools, processes and skills were identified by students as outcomes gained from their HumEng engagement that they did not develop in other courses. Most common were User-Centred Design (UCD) and/or Human-Centred Design (HCD), communication, particularly cross-cultural, and appropriate technology. These were most commonly referenced to as outcomes from international experiences, which included working with translators. Other skills included leadership, teamwork, problem-solving and CAD (particularly in relation to assistive technology). For example, Karen stated "probably the best things that I've learnt from it was human centred design" while Fred found "a whole bunch of cross cultural stuff that I don't think I've been exposed to throughout the rest of my degree." These are broadly seen in the learning gains in Table 4 although without the same level of detail as interviews.

Outcome 3 - Personal Beliefs

Some students identified changes in their beliefs or values, particularly views of "privilege", although participants did not use that term. This was common from involvement in an international experience through an increase in the awareness of quality of life in Australia compared to other countries. "I definitely think the [EWB] summit changed my view on just day to day stuff and it makes me just so much grateful and things like that" said Karen, while Kelly highlighted "… that perspective of understanding how well off and how good we do have it here…"

Outcome 4 - Social and Enjoyment

Students described a level of enjoyment from being involved in HumEng, mostly linked to international experiences, which could include travel, making friends and networks, and having fun. For example one participant said "… I did form a really nice friendship group out of it." However, this often extended beyond just friends to the culture of the engagement and sense of shared purpose such as "A sense of community in engineering." (anonymous) and Ben "Yeah, so the culture was really good, and again, going back to that friends, really fit well into the culture, personally. And, you know, I had a great time. It was very inclusive." For others such as Dalia, HumEng become the focal point of their studies "I think that the humanitarian engineering was the best part of my university degree and the most useful part of my six years at uni." This outcome is seen clearly in the highest responses from Table 6.

Outcome 5 - Motivations

Additional motivation was identified as a positive outcome. Some of this was for their overall studies such as Laura "it definitely sort of made me excited about my degree though. I've got to the end of my second year, and I reconsidered if I wanted to be doing engineering, because it wasn't really, I wasn't finding it satisfying, I wasn't enjoying it. And then as soon as I've started doing the humanitarian side it definitely put a bit more inspiration and motivation, and enjoyment." For others there was additional motivation for involvement with HumEng or changes in career motivations, goals or aspirations "I think I've got more confidence to follow a path that I think I can actually do what I wanted to do with my engineering degree and that's to follow some of these other types of fields" (Dalia). This was seen in the changes in motivations in Table 5, where most of the highest responses can be seen as relevant for work in humanitarian action and development.

Outcome 6 - Understanding of Humanitarian Engineering

In additional to tools, skills and processes related to HumEng, an increase in knowledge and awareness of HumEng as an area of practice was identified. This included views of HumEng, with a strong emphasis on collaboration and working and designing "with", the contexts where it can take place, and the range of stakeholders that should be involved. For example, one anonymous student described this as "working with people rather than for them."

Outcome 7 - Engineering Practice

Extending beyond HumEng, outcomes were seen in the application of existing engineering skills, knowledge and theory. For example "I think when we actually say gained engineering skills or knowledge, I think, it's more like how I optimised my engineering skills and knowledge" (anonymous). Other students described a change in their understanding of the role and views of engineering and technology and the work engineers can be involved with Ben saying "…the people side of engineering was really interesting as well. That's something that I didn't really think made such a big impact, is that people side, and how much, you know you're engineering for a person and not just, you know a set of requirements." Some of these can be seen in Table 5, although not in the highest responses.

From the interview analysis and the engagements outlined in Table 3, three distinct student pathways were identified using a similar process to[18]:

1. *Isolated*, where students completed at least two optional engagements with HumEng but in isolation and not integrated into a cohesive pathway by the student. Five students were identified as having completed this pathway (such as Christina and Janet).
2. *Integrated,* where the various engagements built upon each other to create a cohesive pathway within engineering. This was the most common approach with 11 students engaging in this way (including George, Robert, Frank and John).
3. *Holistic,* when students built on the integrated approach and undertook studies with an explicit multi-disciplinary focus or significant studies outside engineering. Five students were found to have completed this approach (Kathy, Karen, Dalia, Alex and Jacinda).

Discussion

Findings

Across all analysis, this research highlights that involvement in HumEng education supports learning for the full range of engineering competencies and demands of a contemporary engineer regardless of career aspirations. Findings generally support previous research in the area undertaken in other countries. For example, three of the categories identified by[1], personal development, understanding theory vs practice, and intercultural competency, can be seen in the outcomes here. Both surveys and interviews identified clear outcomes for students in professional skills[13] and motivations[22]. Table 4 shows similar outcomes to previous studies with the most significant gains in cross-cultural competency, communication, stakeholder engagement and incorporating social factors into engineering. This is similar to results existing work[11,13], and those from the earlier study at the ANU[15].

In addition, this work identified clear links between HumEng education and positive graduate perceptions of employability. This was evident in interviews, potentially as interviewees had recently been through competitive job applications, whereas the link was less emphasised in the international experience survey, which was earlier in students' studies. This enhanced perception fits models of graduate employability where depth in a specific discipline, such as an engineering major, is complemented by breath across professional practice skills and competencies[20]. In the case of HumEng, findings here suggest the latter is provided through service-learning experiences and further supports the use of appropriately scaffolded service-learning approaches to enhance employability[13].

Demographics

Previous studies have highlighted greater engagement from females in HumEng and areas focused on social and community impacts[22,23]. This was found here with the base participation of females in engineering at the ANU 20-23%, while in HumEng it was found to be 40-50% (from Table 2). In addition to a focus on social impact which has been highlighted in other studies[1,23], participants identified a more open and inclusive culture around HumEng, particularly immersive and study abroad experiences. This was mentioned by a number of female participants, perhaps most clearly by Carol "it was great because it was so pleasant. It was very – it was not masculine-dominated […] But with the [EWB] Humanitarian Design Summit, it was just – it was like a Utopian society. It just felt – like just being around people who – like being equals and feeling equal, like the idea that – because it's fifty-fifty". Engagement in HumEng was mentioned by a number of female participants as giving motivations for remaining in their engineering studies by providing a focus or outlet for their engineering and aspirations, as highlighted by Christiana "Humanitarian engineering felt a lot different to me even though it was engineering. It felt a lot more than that."

This demonstrates the potential of HumEng to not only attract greater diversity in engineering studies but assist with retention and building a sense of community and purpose. It could potentially foster an alternative culture within engineering which is more welcoming of diverse individuals and perspectives. The shared sense of purpose or common goal appears to be the most significant factor, a similar finding to[23].

While there was greater gender diversity in the HumEng pathway, it can be seen that students are coming from a position of privilege. None of the students interviewed were in the first generation of their family to attend university, all but one had English as a first language, and only five across both the survey and interview participants were international students. The data indicates that international experiences are potentially more likely to attract students who are from non-urban backgrounds (Table 2). This could potentially be due to a lack of opportunities for those participants while at school. This trend is not seen in the overall engagement in the pathway and again this potentially highlights the privilege linked to greater opportunities and thus engagement. However, students engaging in HumEng were more likely to undertake paid work as the main source of financial support for their studies, 53% for those involved in HumEng international experiences compared to 24% for the 3rd/4th year baseline[21].

Previous work has critiqued HumEng programs from perspectives of social justice and power relationships. Work exploring the benefits and commitments of different stakeholders in study abroad experiences has found that the needs of students can often be inappropriately prioritised[24]. Given the demographics here, such considerations must be factored into program design and discussed with students involved.

Pathways

Students who completed the isolated pathway often referred to engineering and HumEng separately, and had not made explicit links between the two. For example "So, I don't think that a lot of that stuff is directly applicable […] So, I think when engineers here are able to go over and apply what they've learnt, the basic stuff from the more heavy stuff" (anonymous). Students from the integrated pathway combined their HumEng and engineering studies and identify common elements or approaches. However, of the three student pathways identified, those in the holistic group were found to weave their HumEng engagement with their other studies and articulate opportunities for HumEng to be beneficial in all engineering work and society as a whole. For example, Dalia said "I think the main thing I got from all my humanitarian experience […], was this distinction between giving someone a piece of technology that will help and how to empower somebody with that technology. I think that it's something that really changed me as an engineer and how I approach problems even now." This is similar to work such as[11] which highlight the need to create explicit links beyond engineering.

Broadly, two types of graduates were identified, those looking to use HumEng in traditional, non-HumEng engineering roles, and others seeking a career in humanitarian action or development. While the former typically reported greater perceptions of employability, the latter reported challenges with opportunities and career pathways. This can potentially be seen in the lack of work experience in HumEng as shown in Table 3 (only two of the 21 interviewees had completed related work experience). Students from the holistic pathway were the participants most frustrated with seeking employment in an area they saw of value. For example, Jacinda commented "[…] there aren't really graduate jobs in humanitarian engineering; um, there are definitely ways to find some that will lead to them one day […] at least how I'm feeling at the moment is what are the pathways for a humanitarian engineer? I think that's still being figured out."

With the recent growth of programs in Australasia[7], finding HumEng work experience and employment opportunities could potentially be a challenge as the number of graduate's increases dramatically. The changes in career motivations in Table 5 could lead to unmatched career expectations, as highlighted in[22], particularly for females. However, this study found this was not only for female graduates, with Charles saying "It's actually a lot easier to get a job doing mechanical engineering at an injection moulding plant and get paid two or three times more money than do the thing I want to do." This suggests a potential national response is required to provide support and opportunities for those looking for careers. This should engage potential employers and ensure professional practice recognition. Further, students should be supported to make connections between HumEng and all engineering work in addition to thought leadership to help shift the engineering sector to value the creation of positive social impact as core practice.

Curriculum Structure and Development

The research and findings here have been used to shape the design of a new dedicated four-course Minor in Humanitarian Engineering at the ANU. This seeks to replicate and formalise the holistic pathway while supporting greater connections to engineering practice. The elements of the minor are given in Table 7 along with when taken and desired outcomes. The first course is to provide an introduction to development and the opportunity for students to start to engage with non-engineers. It ensures students begin their pathway early, with many interviewees highlighting they would have liked to have started earlier in their studies. The position of the EfaHC course is based on findings here, that students need some engineering background, but is still early enough to provide motivations and outcomes as further engineering study is undertaken. It considers the maturity of students, with interviewees highlighting it was the start of third year when they began to engage deeply with their studies. For example, Ben highlighted "I kind of didn't do anything with humanitarian engineering until, I think, it was around the second or third year, when I started getting involved in EWB a little bit." This parallels findings from[3], that many second year students are not prepared for problem-based service-learning, and appropriate and significant scaffolding needs to be in place.

TABLE 7

STRUCTURE OF FOUR COURSE MINOR IN HUMANITARIAN ENGINEERING AT THE ANU.

Course	When Taken	Outcomes
First year introduction to development course	In first three semesters.	Provide a background to global development.
Engineering for a Humanitarian Context (EfaHC)	Intensive between second and third year, can include a short-term study abroad program.	Students start to explore and connect their engineering and development studies.
Non-engineering context course in areas such as disaster response or community development	Third year.	Depth in a specific context for humanitarian action or development, and approaches taken within them.
Multi-disciplinary engagement course	Fourth year.	Foster connections out from engineering and how engineering can contribute into larger multi-disciplinary work.

The context course provides further depth in an area of interest to the student. The multi-disciplinary engagement course draws from the holistic pathway, with students directly working with non-engineers towards a shared common goal and applying their specialised engineering knowledge gained by final year. This multi-disciplinary engagement was highlighted by recent works[11,13], both of which found greater inclusion of non-technical factors being considered by engineers with social engagement experiences. Beyond the minor, students can complete a final year individual or group research or development project. This structure aligns with the understanding of HumEng in Australasia, where students are weaving a dedicated engineering discipline (such as electronic or renewable energy) with understanding and approaches to apply that to multi-disciplinary humanitarian and development contexts.

Limitations and Challenges

The number of interview participants is comparable to other studies and provides a range of experiences from which to identify outcomes and variation. However, as noted in[11,25], results may not be generalisable due to small sample sizes. The findings here were generally consistent across surveys and interviews, suggesting bias in interviews was not encountered and the mixed-methods approach was appropriate. However, that the same students could complete a survey and interview could over-emphasise some differences as compared to a baseline for all of 3rd/4th year.

There are some places of potential concern that require further work. The overall demographics (Table 2) demonstrate those engaging are domestic, not first in family and have English as a first language, while the first two responses of Table 6 are learning about the country visited and making friends. These results could indicate a particular level of privilege for those taking part, coming from families with established degree qualifications. In this case the critiques of[24] are particularly relevant, and hence the need to continue to incorporate a focus on domestic disadvantage and social justice. It highlights the need for continued work to consider any benefits, outcomes and demands on organisations beyond the university involved with service-learning. While this work focused on students only, outcomes from student work for external partners was mentioned during interviews, without any conclusive outcomes, as highlighted by an anonymous quote "it was probably a different type of value [provided to the partner organisation] to what we were expecting or what we foresaw planned out or whatever when we first started." Impacts on, and resources committed by, communities and partners involved is an necessary area for continued work.

CONCLUSION

From a mixed-methods study exploring outcomes for students from engagement with HumEng it was found participants identified a range of benefits. In particular, the application of engineering and cross-cultural communication were identified as well as study motivations. In turn, this provided greater employability for graduates, as strongly reported across a range of engineering roles and positions. This demonstrates the ability of HumEng to create more effective engineers, able to operate within the current and anticipated engineering practice of the 21st Century. HumEng has the potential to make significant contributions to the development of a more inclusive and welcoming engineering profession, by exposing graduates to such environments and the benefits they bring.

The work here does not seek to generalise the findings, but rather contribute to the growing evidence from multiple studies and institutions about the benefits of HumEng, and its common curriculum approaches, for contemporary engineering practice. This work adds to the findings in countries with similar approaches to engineering education and practice, particularly signatories to the Washington Accord.

From the research here, further studies will include capturing data over a longer period both from graduates within three months of study as well as from the same individuals 1-3 years later. This is particularly relevant to identify challenges for unmatched career expectations and the culture within professional engineering practice. The findings from interviews could be incorporated directly into further surveys to collect data from a larger sample size. This is already being explored across multiple universities in Australia, to build a picture of the impact of HumEng across the country.

This work highlights the need for discussion around understandings of HumEng and related terms, and the competencies and knowledge required of graduates who may seek to work as a Humanitarian Engineer. In addition, interventions are required with graduates and employers for career paths within the field, and to support graduates to link their outcomes from HumEng to any engineering practice to support positive social impact.

ACKNOWLEDGEMENTS

The first author would like to thank all the students who have been involved with humanitarian engineering in their studies, and for their time in completing surveys and taking part in interviews. This work, and the outcomes and positive impacts from it, would not have occurred without them.

REFERENCES

[1] Nassar, A. R., Holmes, K., and Mehta, K. (2016). Student outcomes of short-term international humanitarian engineering fieldwork. *Frontiers in Education Conference* (FIE), IEEE pp 1–9.

[2] Muñoz, D. R., and Skokan, C. K. (2007). Humanitarian engineering programme: conceptual challenges. *World Transactions on Engineering and Technology Education*, 6(2), pp253–255.

[3] Pierrakos, O., Nagel, R., Pappas, E., Nagel, J., Moran, T., Barrella, E., and Panizo, M. (2013). A mixed-methods study of cognitive and affective learning during a sophomore design problem-based service learning experience. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, Fall, pp 1–28.

[4] Lam, J. W., Mah, F. J., Miller, P. B., and Meikleham, A. (2016). Developing Role Models for Engineering and Sustainable Development: Engineers Without Borders' Global Engineering Certificate. *New Developments in Engineering Education for Sustainable Development*, W. Leal Filho and S. Nesbit, Eds. Cham: Springer International Publishing, pp 139–149.

[5] Hill, S., and Miles, L. (2012) What do Students understand by the term "Humanitarian Engineering"? In *Innovation, Practice and Research in Engineering Education*, Coventry University, UK, pp 1–11.

[6] Johnson, F., Foster, S., Frankel, C, Johnson, S., Moore, S., Stuetz, and Thomas, J. (2017). Making a difference: creating opportunities for undergraduate students to contribute to humanitarian engineering projects. *28th Annual Conference of the Australasian Association for Engineering Education* (AAEE1017) Order of Proceedings, Manly.

[7] Smith, J., Anderson, B., Brown, N., Colley, A., Stoakley, A., and Turner, J. (2017). The Rise of Humanitarian Engineering Education in Australasia, *2 8th Annual Conference of the Australasian Association for Engineering Education* (AAEE1017) Order of Proceedings, Manly.

[8] Thomas, J., Matous, P., Café, P., and El-Zein, A. (2017). Lessons Learned from the design and delivery of a new major in Humanitarian Engineering. *28th Annual Conference of the Australasian Association for Engineering Education* (AAEE1017) Order of Proceedings, Manly.

[9] Turner, J., Brown, N., and Smith, J. (2015). Humanitarian Engineering – What does it all mean? *26th Annual Conference of the Australian Association for Engineering Education (AAEE2015)* Order of Proceedings.

[10] Mazzurco, A., and Jesiek, B. K. (2017). Five Guiding Principles to Enhance Community Participation in Humanitarian Engineering Projects. *Journal of Humanitarian Engineering*, 5(2), pp 1–9.

[11] Payne, L., and Jesiek, B. (2018). Enhancing Transdisciplinary Learning through Community-Based Design Projects: Results from a Mixed Methods Study. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, 13(1), pp1–52

[12] Bielefeldt, A. R., and Canney, N. (2014). Social Responsibility Attitudes of First Year Engineering Students and the Impact of Courses. Presented at the *121st ASEE Annual Conference & Exposition, Indianapolis*, IN, USA: ASEE.

[13] Litchfield, K., Javernick-Will, A., and Maul, A. (2016). Technical and Professional Skills of Engineers Involved and Not Involved in Engineering Service: Technical and Professional Skills of Engineers in Engineering Service. *Journal of Engineering Education*, 105(1), pp 70–92.

[14] Burnham, M. G. (2009). The 'systems approach' to human problems: How humanitarian engineering can help. *ISTAS'09. IEEE International Symposium on Technology and Society*, pp 1–10, IEEE.

[15] Smith, J., Compston, P., Male, S., Baillie, C., and Turner, J. (2016). Intensive Mode Teaching of a Humanitarian Engineering Course to Enhance Service-Learning. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, 11(2), pp 38–54.

[16] Huff, J., Zoltowski, C. B., Oakes, W. C., and Adams, R. (2013). Making Sense of Design: A Thematic Analysis of Alumni Perspectives. *Presented at the 120th ASEE Annual Conference and Exposition,* Atlanta, USA.

[17] Litchfield, K., and Javernick-Will, A. (2015) "I am an Engineer AND": A Mixed Methods Study of Socially Engaged Engineers. *Journal of Engineering Education and Practice*, 104(4), pp 393–416.

[18] Pasque, P. A., Bowman, N. A., Small, J. L., and Lewis, R. (2009). Student-Created Curricular and Co-Curricular Pathways Toward Participation in a Diverse Democracy. *Multicultural Perspectives*, 11(2), pp 80–89.

[19] Creswell, J. (2003). *Research design: Qualitative, quantitative, and mixed-method approaches*, 2nd edition, Sage Publications, California.

[20] Kinash, S., Crane, L., Judd, M., Knight, C., and Dowling, D. (2015). What students and graduates need to know about graduate employability: Lessons from National OLT research. *Higher Education Research and Development Society of Australasia Conference*, Melbourne, July 2015.

[21] Smith, J., Mazzurco, A., and Compston, P. (2018) Student engagement with a humanitarian engineering pathway. *Australasian Journal of Engineering Education*, 23(1), pp 40–50.

[22] Litchfield, K., and Javernick-Will, A. (2017). Socially Engaged Engineers' Career Interests and Experiences: A Miner's Canary. *Journal of Professional Issues in Engineering Education and Practice*, 143(1).

[23] Stoakley, A., Brown, N. J., and Matthee, S. (2017). The role of a humanitarian focus in increasing gender diversity in engineering education. *28th Annual Conference of the Australasian Association for Engineering Education* (AAEE1017) Order of Proceedings, Manly.

[24] Vandersteen, J. D. J., Baillie, C., and Hall, K. (2009). International humanitarian engineering. *IEEE Technology and Society Magazine*, 28(4), pp 32–41.

[25] Canney, N., Bowling, T., and Bielefeldt, A. R. (2013). In their own words: Engineering students' views on the relationship between the engineering profession and society. Presented at the *120th ASEE Annual Conference and Exposition,* Atlanta, USA.

APPENDICES

TABLE 8

SINGLE AND DOUBLE DEGREES AND MAJORS FOR PARTICIPANTS (STUDENTS CAN POTENTIALLY COMPLETE TWO MAJORS) AND A 3RD AND 4TH YEAR BASELINE FOR COMPARISON (% VALUES IN BRACKETS).

Study	Interviews (%)	Survey (%)	Base 3rd/4th (%)
Reponses (N)	21	26	165
Single Degree	10 (48)	16 (62)	133 (80)
Double Degree	11 (52)	10 (38)	32 (20)
B Engineering	21 (100)	25 (96)	147 (89)
B Engineering (R&D)	0 (0)	1 (4)	18 (11)
Biomedical Systems Major	1 (5)	5 (17)	14 (8)
Electronic and Communication Systems Major	2 (10)	3 (10)	63 (38)
Mechanical and Material Systems Major	13 (62)	9 (30)	58 (35)
Mechatronics Systems Major	2 (10)	4 (13)	26 (16)
Renewable Energy Systems Major	3 (14)	8 (27)	16 (10)
Sustainable Systems	0 (0)	1 (3)	3 (2)

Vol. 14, No. 1, pp. 1-20, Spring 2019
ISSN 1555-9033

TABLE 9

INTERVIEW PARTICIPANT DETAILS (M IS MALE, F IS FEMALE), PSEUDONYMS WHERE USED (PARTICIPANTS COULD ELECT TO REMAIN ANONYMOUS), AND EXPERIENCES UNDERTAKEN DURING UNDERGRADUATE STUDIES.

Pseudonym (or Anonymous)	Gender	EfaHC	Study Abroad	Final Year Project	Extra-Curricular Activities	Cross-Disciplinary Course	EWB Challenge
Anonymous	M	Y		Individual			Y
Anonymous	F	Y			Y		Y
Anonymous	M		Y	Team			Y
Alex	M		Y	Individual	Y	Y	Y
Ben	M		Y	Individual	Y		Y
Carol	F	Y	Y		Y		Y
Charles	M	Y	Y				Y
Christiana	F	Y		Individual			Y
Dalia	F	Y	Y	Individual		Y	Y
Frank	M			Individual			Y
Fred	M	Y	Y	Individual	Y		Y
George	M	Y	Y	Individual	Y		Y
Jacinda	F	Y	Y	Individual		Y	Y
Janet	F		Y	Individual			
John	M	Y	Y	Individual			Y
Karen	F	Y	Y	Individual		Y	Y
Kelly	F	Y	Y	Individual		Y	Y
Laura	F	Y	Y	Individual	Y		Y
Lee	M	Y	Y	Individual			Y
Robert	M			Individual			Y
Tom	M	Y	Y	Individual			Y

Interview Prompts

Below are question prompts used during semi-structured interviews in the approximate order they are asked.

1/ What study program did you, or are you about to, complete? Why did you study engineering or become an engineer? What were some of your motivations?

2/ What was your first exposure to humanitarian engineering? Was it outreach, EWB Challenge, a media/news article, a friend, parent, teacher, …? Was this before or after you started you degree?

3/ Describe your humanitarian engineering experience at ANU. What humanitarian engineering experiences have you had? What humanitarian engineering education initiatives have you involved with while studying? Were you involved with any outside activities? What project topics or assignments did you undertake?

4/ What were your initial motivations or reasons for engagement with humanitarian engineering? What factors lead to you undertaking these initiatives or experiences? Were there any external factors that encouraged or influenced you?

5/ Did these the same motivations or factors change over time?

6/ What engineering skills or knowledge do you think you have developed or gained from your humanitarian engineering experiences? Did humanitarian engineering education, initiatives or experiences give you skills, knowledge, experience or learning that you did not get in other parts of your studies? What were some of these?

7/ What impact, if any, did your humanitarian engineering education have on your overall time as a student? Did humanitarian engineering education provide motivations for your studies more broadly? Were there any other outcomes?

8/ How well could you integrate or relate your humanitarian engineering education experiences with your studies? Were they complementary or overlapping or supporting each other? How was the flow or your 'program'?

8a/ What impact do you think your humanitarian engineering experiences had outside your studies, with partners? Did you provide any outcomes to external groups?

10/ How applicable are the skills or knowledge you gained to your current or future work or engineering work in Australia? How, are you or could you apply these skills or knowledge? In what areas or contexts?

11/ During any interviews or gaining employment after graduation, do you think any of your humanitarian engineering experiences were of interest or particularly relevant? Did you employers / interviewers so interest in any? Do you think your humanitarian engineering education contributed to your employment or prospects?

12/ Do you think you will stay in engineering or your current employment?

13/ Do you want to work in humanitarian assistance or development now or in the future? What do you feel prepared for?

14/ Was there anything you particularly enjoyed about humanitarian engineering? How did you find the culture around your HE studies particularly compared to the rest of your studies?

15/ Did you have any frustrating experiences from studying humanitarian engineering? Anything lacking or gaps? Were there any barriers to your humanitarian engineering education experiences or undertaking further experiences? Would you like to have had more or less or different humanitarian engineering education experiences?

16/ What do you consider humanitarian engineering? Is it all engineering? Do you think humanitarian engineering is an appropriate or meaningful name? Did you think humanitarian engineering is important, and if so why?

17/ Do engineers have a role to play in humanitarian work? What role does technology have to play in humanitarian work? Should all engineers have some education in humanitarian engineering?

International Journal for Service Learning in Engineering,
Humanitarian Engineering and Social Entrepreneurship
Vol. 14, No. 1, pp. 1-20, Spring 2019
ISSN 1555-9033

18/ Do engineers have a role in improving society or overcoming social problems? Do you think technology has a role to play in improving society? If so, what role? Do engineers have a responsibility for the outcomes of their engineering work or technology they create? What form may that responsibility take?

9/ Do you think you should have had some 'recognition' for your humanitarian engineering studies? A certificate, a qualification, …?

Chapter 8: Integrating Professional and Discipline Practice to Enhance Student Motivation and Employability

Foreward

Building from the substance of the thesis, a new program design for the common core of the engineering degree at the ANU is outlined here. The Chapter takes the findings and insights of the research as a whole and abstracts them to underpin the design of a suite of multiple application pathways. These are to link student interest in a domain area with the rest of their studies in order to achieve the general benefits and positive outcomes found in the Humanitarian Engineering (HumEng) pathway designed and evaluated in this study.

Rather than specifically addressing the research questions, this Chapter looks more deeply at the findings to gain lessons for engineering education broadly beyond HumEng. Data and analysis from across the research is used to provide the foundations for the proposed program design. Enabling students to have a range of curriculum experiences, building on students' motivations, and opportunities to practice and apply their engineering were found to be elements that were key to students gaining positive outcomes from the HumEng pathway. However, these elements are not unique or specific to HumEng, and with an appropriately designed degree program, they should be able to be used to enhance the learning of any engineering student. This links to T-shaped graduate models which combine discipline practice depth with cross-disciplinary breadth. The findings in this Chapter suggest a better integration between depth and breadth elements can be achieved by providing early opportunities for students to apply their knowledge in areas of interest to them.

The basic model outlined here, of multiple application pathways running in parallel across a student's studies, from second to fourth year, has been proposed for the engineering undergraduate degree at the ANU. In this way, this Chapter demonstrates the broader impact of this study, not just for students interested in HumEng, but across all engineering students at the ANU, which was beyond the initial scope of the study.

Integrating Professional and Discipline Practice to Enhance Student Motivation and Employability

Jeremy I. Smith, *Member, IEEE*, Chris Browne, and Paul Compston

***Abstract*—This study develops a new program level design for an undergraduate engineering degree which integrates domain specific project-based learning opportunities with professionally accredited certification frameworks. To meet employer demands and enhance employability, graduates are increasingly expected to have both depth in a specific discipline and breadth across professional practice and cross-discipline skills, captured in the "T"-shaped graduate model. To achieve this requires cohesive pathways that weave discipline and engineering practice together while minimizing changes to degree programs, which are challenging and potentially costly to undertake. To develop a program level design, the requirements of a T-shaped graduate were explored along with educational experiences that can develop this. A pilot application pathway with a focus on humanitarian and development contexts at a single institution was developed. This built on existing project-based courses supplemented by intensive experiences at key points and involvement with the NAE Grand Challenge Scholars Program. This provided an external framework for students to have both credit-bearing and extra-curricular activities recognized. A mixed-methods study was conducted to investigate the students engaging with the pathway and the outcomes they gained. This found students were identifiable as T-shaped graduates, with greater appreciation of, and experience with, professional skills and the application of engineering. The approach for the pilot pathway is being expanded across the degree program, to have multiple application domain pathways in parallel to match student interests, leading to a number of existing certificate frameworks in order to support employability and create individual learning journeys.**

***Index Terms*—employability, gender diversity, higher education, mixed-methods, motivation, professional skills, program design**

I. Introduction

As has been widely recognized, engineers of the 21st century need new skills, knowledge and abilities to operate across the complex, multidisciplinary work and challenges they face [1, 2]. One approach promoted to meet this demand is the "T"-shaped graduate, with the ability to work across, and engage with, multiple industries and stakeholders. The horizontal bar emphasizes interdisciplinary aptitude, professional breadth, and cross-disciplinary skills. This complements depth in one particular discipline area such as a specific engineering discipline, represented by the vertical line [3, 4]. T-shaped graduates are reported to be in greater demand from employers for their ability to connect their discipline depth with additional areas across technical disciplines to other sectors such as business and commerce, and complement traditional "I" shaped technical experts [3, 4, 5]. The need for T-shaped graduates is seen across scientific and technical roles including water professionals [5] and software engineers [6] as well as for graduates in general [7].

To support the education of T-shaped graduates, the design of engineering degree programs must be considered. This includes the level of, and integration between, discipline and professional learning as well as the role of extra-curricular activities such as volunteer work, involvement in clubs and societies, and work experience [7, 8].

This study examines the demand for T-shaped graduates and educational experiences which can encourage the development of breadth and depth skills in engineering graduates. It aims to establish a program level design to develop T-shaped graduates by integrating existing opportunities, student interest, and curriculum, with minimal changes to current program designs and resources.

In the next section, existing research on contemporary employability demands will be outlined along with curriculum approaches to support this, followed by the pilot pathway developed. The mixed-methods research study used to evaluate student engagement and outcomes from the pilot is provided. A discussion on the findings and evaluation of the program design is given along with an outline of planned extensions to the approach developed.

II. Existing Research

A number of factors have been identified from research which contribute to engineering graduates meeting the T-shaped model. Critical are educational programs that provide an emphasis on employability (including creating new businesses not only working for existing organizations), fostered through individual student pathways incorporating and recognizing a wide range of for-credit and extra-curricular

Paper submitted March 2019.
Jeremy I Smith is a Lecturer in the Research School of Electrical, Energy and Materials Engineering at the Australian National University (ANU) in Canberra, Australia (e-mail: jeremy.smith@anu.edu.au).
Chris Browne is a Lecturer in the Research School of Electrical, Energy and Materials Engineering at the ANU in Canberra, Australia.
Paul Compston is a Professor in the Research School of Electrical, Energy and Materials Engineering at the ANU in Canberra, Australia.

learning experiences. These three areas are discussed below.

A. Employability

There has been an increased focus on ensuring employability for university graduates. Based on research in Australia from over 700 surveys and 85 interviews and focus groups covering students, graduates, employers and higher education professionals, a "Graduate Employability Framework" was developed [7]. This emphasized T-shaped graduates, explicitly linking a wide-range of experiences and skills to employability. While highlighting the importance of career goals, identity and professional skills, elements required for employability included internships, work experience, and co-curricular activities, educational activities that often do not contribute directly to formal award qualifications. Employers have also highlighted the importance of work-based learning, including work experience and internships, demonstrating the need for recognition of experiential learning for employability skills by employers and graduates [9].

B. Extra-Curricular Learning

One specific form of experiential learning which has been shown to have a positive impact on the breadth of a T-shaped graduate is Learning Through Service (LTS). Here students engage with external organizations, typically community-based or not-for-profits, learning from the experience while providing a service to the external group [10]. Service-Learning (SL) are LTS experiences where student involvement is recognized with course credit, most commonly through project-based and study abroad opportunities, otherwise LTS is undertaken as co- or extra-curricular. Research on LTS in engineering education in the US has highlighted that often such experiences are not recognized for course-credit, particularly if they involve an international component [10]. This is despite the benefits for student learning including core engineering knowledge and skills, attitudes towards engineering work, and professional performance [11]. Large-scale studies have demonstrated that engineers engaging in socially-focused experiences present in LTS have greater appreciation and inclusion of professional skills than those not exposed to socially-focused experiences, while achieving comparable levels of technical skills [12]. This was found to be due to the opportunities to practice and engage beyond the classroom.

C. Contextualized and Personal Learning

As well as generating more employable graduates, a T-shaped emphasis can promote engineering in multiple-ways, thus increasing the overall interest in the field [13]. For example, in addition to greater experience with professional skills, the social-focus of LTS has been shown to attract and retain greater diversity, particularly for females which are significantly under-represented in engineering [11, 14].

Other works have emphasized the need for program designs that allow students to undertake their own individual pathway to their qualifications. Non-linear progressive programs to encourage diversity and create T-shaped graduates is one approach [4]. Flexible learning paths was one of four key strategies for the education of T-shaped water professionals, highlighting individuals learn and develop in different ways [5] which further encourages diversity and builds inclusion.

III. Program Design

From the existing research, the case for T-shaped graduates highlights the need for innovative and flexible educational program designs that encourage and recognize opportunities for external engagement and a broad range of experiences. To investigate these elements, a pilot pathway was designed and embedded within an existing undergraduate engineering program at a single Australian institution. This aimed to encapsulate the elements identified from existing research including flexibility for students, integration of multiple curriculum approaches, and recognition for student learning from all education experiences, both for-credit and extra-curricular. The goal was such an education pathway would allow students to develop and demonstrate breadth skills as well as discipline depth, enhance their employability, and encourage greater diversity in the student cohort. The focus for the pilot pathway was a contextual application emphasis on Humanitarian Engineering (HumEng) aligned to the National Academy of Engineering (NAE) Grand Challenge Scholars Program (GCSP) certificate framework.

A. Contextual Focus

The focus of the pilot pathway in HumEng was chosen as area of growing interest for engineering, particularly in developed countries such as Australia, USA, Canada, New Zealand (NZ) and the UK. Different definitions and understandings of HumEng exist, but within Australia and NZ it is taken as engineering with a focus on disadvantaged, marginalized, and vulnerable communities or individuals within short- and long-term humanitarian and development contexts domestically and overseas [15]. This means engineers could be working on long-term community development projects such as small-scale rural renewable energy systems [16], through to post-disaster response in domestic contexts [17]. HumEng is a rapidly growing area of practice, with organizations such as Engineers Without Borders (EWB) around the world, Engineering for Change (EfC) and professionally aligned groups including IEEE SIGHT (Special Interest Group in Humanitarian Technology). By its nature, HumEng requires a cross-discipline approach, with engineers providing their expertise alongside specialists in humanitarian action, community development, health, education, and public policy [2,18], making it an appropriate focus for a pathway to potentially develop T-shaped graduates.

B. Institutional Setting

The new pathway was to be implemented within a single engineering School where all students do a project-based systems engineering core while selecting a discipline major half way through second year. This provides a common core for students where multiple project topics can be embedded. The core includes courses with a focus on technical (such as systems design and analysis), professional (engineering management and innovation), and project-based learning (final year capstone and individual research project courses). The engineering degree is accredited by the national professional engineering association, Engineers Australia (EA), and meets requirements for international mobility such as the Washington Accord.

C. *Pathway Structure*

The HumEng pathway was created by providing project and assignment topics in existing compulsory core courses, a new *Engineering for a Humanitarian Context* (EfaHC) elective course using a shell special topic course, and partnerships to support a range of LTS activities. These included individual and group research and design SL projects in final year, short-term study abroad opportunities with a HumEng focus (such as EWB Design Summits), and domestic volunteering and engagement opportunities with community groups including the local chapter of EWB-Australia (EWB-A, a separate organization to other national EWB's). All students at the institution undertook the EWB Challenge (from EWB-A) in first year. This is a design challenge initiative where students work on a range of topics identified by EWB-A and one of its community partners in areas covering energy, water, ICT, disaster management, and education.

This range of initiatives meant students could elect to undertake a HumEng opportunity in each of their year levels, building from the small-scale EWB Challenge in first year, through short-term study abroad, electives, and assignments topics in second and third year, though to potentially year-long SL projects [19]. Fig. 1 shows the specific HumEng related components alongside the program elements which all engineering students at the institute take and how HumEng opportunities are available through those.

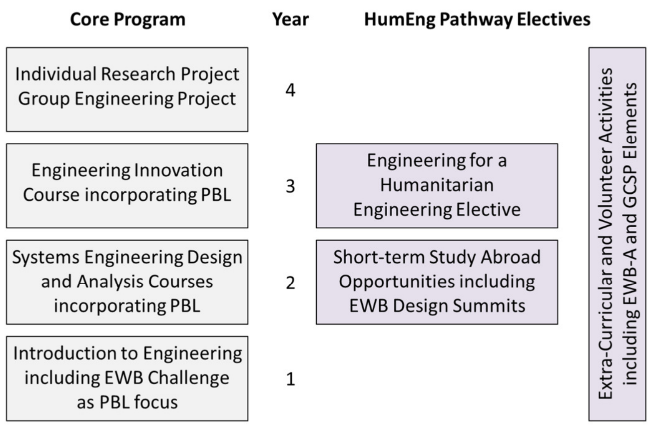


Fig. 1. Existing core program elements into which HumEng projects and opportunities can be embedded, typically through Project-Based Learning (PBL), alongside optional HumEng Pathway elements, allowing a student to undertake a HumEng opportunity in each year level.

D. *Certificate Framework*

To complement the HumEng pathway and provide recognition for students, the university applied to the National Academy of Engineering (NAE) Grand Challenge Scholars Program (GCSP). Growing out of the US, this provides a certification framework focused on the NAE's 14 Grand Challenges for Engineering for the 21st Century [20]. Once accepted, individual institutions implement the GCSP according to their aims and resources, and are responsible for supporting students and accrediting Scholars. If a student at a university involved in the Program demonstrates their engagement across five key elements (or competencies) of contemporary engineering for one or more of the 14 Grand Challenges, they receive an additional certificate from the NAE recognizing them as a Grand Challenge Scholar. The five elements are talent (a research or creative experience), multidisciplinary, viable business or entrepreneurship, multicultural (for example an international experience), and social consciousness (such as LTS). As can be seen, these areas capture many of the elements of a T-shaped graduate, particularly the explicit multidisciplinary focus. Experiences which can contribute to the five competency elements can be drawn from for-credit and extra-curricular activities providing flexibility for students and support individual learning paths.

IV. Research Design

The HumEng pathway described above was completed in 2015, with the institution being accepted into the GCSP by the NAE in 2016. To explore the impacts of these initiatives on students, a mixed-methods research study was designed. The study enabled quantitative data from student enrolment, surveys, and engagement to be combined with qualitative data from interviews and open-ended questions. Mixed-methods studies have been used to explore student outcomes from education innovations as they provide flexibility in data collection, the opportunity for data triangulation, and to explore emerging outcomes without prescribed theories or frameworks [21]. Within engineering education, mixed-methods studies have been widely used to explore involvement in LTS and HumEng, which are two key elements within the study here. This has included research into socially-focused engineers [14], problem-based service-learning [22], community-based multidisciplinary design projects [18], and study abroad experiences [23].

For example, six beneficial categories were identified using grounded theory analysis of 106 student reflections upon completion of a three-week HumEng focused study abroad experience [23]. The categories were *resourcefulness and innovation*, *teamwork*, *intercultural competency*, *professionalism*, *understanding theory vs practice* and *personal development*. As can be seen, many of these relate to the breadth requirement of a T-shaped graduate. From a larger mixed-methods study, students and graduates with exposure to socially-focused engineering were found to have greater levels of professional skills with the same level of technical skills as those without social experiences [12].

The research design in this study utilized a concurrent nested strategy [24]. This involved multiple data collection across quantitative and qualitative methods in parallel, with data integrated during analysis where possible. Emphasis was placed on the qualitative results gained from student interviews, hence the quantitative results from surveys were nested into the overall strategy [24]. This approach enabled triangulation of data across sources to support findings. All aspects of the research were conducted under the institutions' human ethics guidelines and approved by the relevant committee.

Data collection included anonymous student surveys before and after key initiatives within the HumEng pathway, particularly the EfaHC elective, research projects, and short-term study abroad experiences. Surveys captured a range of data based on previous research including demographics, study, involvement with clubs, societies, extra-curricular and professional experience, attitudes to study, motivations, and outcomes gained from experiences.

To provide a comparison between students engaging in HumEng and the overall student cohort, an anonymous baseline survey of all third and fourth students at the institution was conducted. This was feasible due to the institutional setting, where engineering was housed within a single School and all engineering students undertook the same compulsory core courses. The baseline survey included questions covering elements of the HumEng surveys such as demographics and background, as suggested by previous studies [22]. In order to capture a complete baseline, those involved in HumEng activities also had the opportunity to complete the survey through third and fourth year courses.

The main qualitative results were collected from interviews with students within three months of graduation. This used a targeted sampling strategy, inviting students who had completed two or more optional HumEng experiences from the pathway over their studies. For example, this could include a study abroad experience and a research project, or the EfaHC elective and involvement in volunteer activities. Interviews were conducted by the first author, typically lasting 30-60mins. Interviews were recorded, transcribed and analyzed using an open-coding method including three researchers to identify key themes. During interviews students could reflect on their overall time at university as well as recent experiences seeking employment after university, as students typically apply for graduate positions throughout their final year.

V. Results

Mixed-methods data over an 18-month period was collected from a survey after a two-week short-term study abroad HumEng experience (labelled *international post-survey*), before commencing a substantial research project (*research pre-survey*), and from interviews with students upon graduation (*interviews)*. During this period, a baseline survey of all third and fourth year engineering students was completed for comparison. Table I shows the overall number of participants, response rates and key demographics. A complete list of the interviewees is given in the Appendix which outlines the experiences participants undertook in their HumEng pathway.

TABLE I
DEMOGRAPHICS OF INTERVIEW AND SURVEY PARTICIPANTS AND A COMPARISON 3RD/4TH YEAR BASELINE

Demographic	Interview	International Post-Survey	Research Pre-Survey	3rd/4th Year Baseline
Participants (N)	21	30	24	165
Response Rate (%)	81	n/a	n/a	64
Domestic Student (%)	95	90	88	57
Average Age (Years)	23.3	21.3	23.5	22.0
Gender (F/M/OI*) (%)	43/57/0	43/57/0	29/71/0	22/76/2
English as First Language (%)	95	83	88	51
First Generation in Family to attend University (%)	0	13	13	15
Australian Aboriginal or Torres Strait Islander (%)	0	0	0	0
Urban Background (%)	86	73	79	82

* F is Female, M is Male, OI is Other or Intersex.

Anonymous surveys were conducted upon completion of an optional HumEng two-week study abroad experience (described in detail in [25]). Agreement with a set of potential learning gains and outcomes are shown in Tables II and III respectively.

TABLE II
RESPONSES TO LEARNING GAINS FROM AN OPTIONAL INTERNATIONAL HUMENG EXPERIENCE, FROM *NONE (1)* TO *SIGNIFICANT (4)*, ORDERED BY % 4 RESPONSES

Learning Gain	4	3	2	1	% 4
Cross-cultural awareness	26	3	0	1	87
Engaging with users or stakeholders	24	5	1	0	80
Ability to work internationally	24	5	1	0	80
Communication skills^	23	4	1	1	79
Ability to incorporate social factors into engineering	21	9	0	0	70
Application of engineering to the real-world	19	10	1	0	63
Ethical practice^	17	7	5	0	59
Incorporating sustainability into engineering^	15	9	5	0	52
Adaptability	15	14	1	0	50
Creativity	14	12	3	1	47
To the systems engineering core^	13	13	3	0	45
Ability to work on complex problems	13	12	5	0	43
Teamwork skills	12	14	4	0	40
Engineering design^	11	13	5	0	38
To my discipline major^	3	1	12	12	10

* From a total of 30 responses (N=30)
^ One nil response

TABLE III
RESPONSES TO OUTCOMES FROM INVOLVEMENT IN AN OPTIONAL INTERNATIONAL HUMENG EXPERIENCE FROM *STRONGLY DISAGREE* (1) TO *STRONGLY AGREE* (5) ORDERED BY % 5 OR 4 RESPONSES

Statement	% 5,4	% 3	% 2,1
I learnt about the country I was visiting	100	0	0
I made new friends	97	3	0
This was relevant for my current studies	97	3	0
I learnt about my role as an engineer	97	3	0
I learnt new engineering skills and knowledge	93	0	7
I used or applied my engineering skills or knowledge	86	10	3
I can better connect my studies to the application of engineering knowledge	83	17	0
I am more likely to find employment	76	24	0
I had a sense of individual achievement	76	21	3
I am more motivated to be an engineer	69	28	3
I am more motivated to complete my studies	66	34	0
I was able to communicate with everyone I met	62	28	10
I made a positive contribution to the country I was visiting	55	38	7
My presence had a negative impact on the country	0	3	97

* From a total of 30 responses with one nil response (N=30)

Table IV shows the attitudes towards different areas required to be a professional engineer with results provided for a HumEng research experience pre-survey, HumEng international experience post-survey, and the overall baseline.

TABLE IV
VIEWS ON THE IMPORTANCE OF DIFFERENCE AREAS FOR ENGINEERING PRACTICE FROM A 1 TO 4 SCALE GIVING THE % OF *SIGNIFICANT* (4) RESPONSES ACROSS THREE PARTICIPANT GROUPS

Area	International Post-Survey	Research Pre-Survey	3rd/4th Year Baseline
Professional skills	81%	96%	70%
Ethical practice	75%	75%	45%
Interdisciplinary knowledge	56%	21%	20%
Systems engineering	50%	50%	30%
Engineering Discipline knowledge	40%	22%	47%
Research skills	38%	33%	30%
Technical skills	38%	25%	45%
Business skills	31%	25%	19%
Fundamental knowledge	25%	46%	47%

From analysis of data across surveys and interviews, seven outcome themes were identified from engagement in the HumEng pathway. These are listed below with a brief description and example interview quote (see [26] for further details on the analysis and themes):

1) *Employability*
Students had an enhanced perception of their employability; "Because that became one of the key points in a lot of my interviews actually, just discussing about my different experiences while I was overseas, you know, and the whole teamwork, how to face the challenges, how I was able to adapt, and a lot of the fundamental skills that employers are looking for, I was able to give a lot of examples from the design summit, and from my research project" (Jacinda).

2) *Tools, Processes and Skills*
New tools, processes and skills not gained elsewhere in their studies such as human-centered design and cross-cultural communication; "I think they would see it and be like, oh, this guy has done his degree, but he's also gone one step further and decided to do something like voluntarily. Then they probably assumed that you've developed a lot of skills from it. Because it's not hard to write that you have gained a lot of skills from it, because you definitely have" (Lee). The outcomes from involvement with an international intensive experience (Table II) are mostly in breadth and professional skill areas including *cross-cultural awareness* (87% agreement) and *communication skills* (79%) as the first and fourth highest ranked responses.

3) *Personal Beliefs*
Related to perceptions of privilege and disadvantage; "… that perspective of understanding how well off and how good we do have it here [Australia]…" (Kelly).

4) *Social and Enjoyment*
An enjoyment of the experiences and positive perceptions of inclusion and peer friendships; "A sense of community in engineering" (Anonymous). As seen in Table III, *making new friends* was the equal second top response.

5) *Motivations*
Increased motivations, for potentially the rest of a students' engineering studies or changes in career goals and aspirations, often to work in more development or people-centric roles; "It definitely sort of made me excited about my degree though. I've got to the end of my second year, and I reconsidered if I wanted to be doing engineering, because it wasn't really, I wasn't finding it satisfying, I wasn't enjoying it. And then as soon as I've started doing the humanitarian side it definitely put a bit more inspiration and motivation, and enjoyment" (Laura).

6) *Understanding of Humanitarian Engineering*
An increase in knowledge of the field and its range of potential applications and benefits; "working with people rather than for them" (Anonymous).

7) *Engineering Practice*
The opportunity to apply a range of engineering skills, but also of the role of engineering practice broadly; "it gave me that other way of thinking through engineering, not just technical, but also, I don't know, is it dynamically, you're just thinking about the whole overall problem and how it can be – how engineering can apply in the real world" (Anonymous). Across Tables II and III, *using engineering skills*, *application of engineering to the real-world*, and *connecting engineering with application*, rank highly (86%, 63%, and 83% agreement respectively).

Detailed data has not been collected from the GCSP on activities undertaken and challenges addressed. The number and gender of graduates and students currently in the program since its establishment (end of 2016 to end of 2018) is shown in Table V.

TABLE V
NUMBER OF PARTICIPANTS INVOLVED, OR GRADUATED FROM, THE GCSP AT THE INSTITUTION (2016-2018)

Participants	Female	Male	Total
Graduated	5	2	7
In Program	3	6	9
Total	8	8	16

VI. DISCUSSION AND INSIGHTS

The results in the previous section were first considered from a student perspective to assess positive outcomes, if any, for employability and future engineering practice from the pilot pathway. The pathway design as a whole was then evaluated. From these two areas, findings were abstracted to create a conceptual program design for engineering as a whole at the institution.

A. *Student Outcomes*

The pilot pathway developed helps students connect discipline studies with application, particularly through the common core. This is seen in outcomes 1, 2 and 7, employability, tools, processes, and skills, and engineering practice respectively. This matches the T-shaped model, with students developing professional breadth to supplement their discipline depth.

When comparing the importance of different areas of engineering practice for the HumEng cohort with the overall baseline in Table IV, there are noticeable differences related to T-shaped graduates. While all groups rank *Professional Skills* the highest, those in the application pathway rate it more highly (by 10-20%). They also rank Ethical Practice as the second most significant, rating it more highly than the overall cohort (75% compared to 45%), and attached higher value to Systems Engineering (50% compared to 30%). All other areas, including *Discipline Knowledge*, are similar across the groups. These are consistent with findings from other studies where service-learning and the external engagement it brings develop greater appreciate of professional skills in engineering without decreasing the value of discipline knowledge [12, 23].

B. *Pathway Outcomes*

The results indicate the focus on an application of engineering rather than a discipline attracted greater diversity, as seen in student demographics (Table I) and GCSP participants (Table V). It can also be seen that the further the experience is from traditional education approaches, the higher the female participation. For example, the female participation in an international experience, which is completely optional, is 43%, while for a research project, which all students have to complete, it is 29% for a HumEng focused project, which is still higher than the baseline of 22%. This could be due to the application domain here, focusing on HumEng, which has been shown to promote greater gender diversity [14], as well as SL approaches in general [11].

Combined with student outcomes for employability and nurturing T-shaped graduates, the pilot pathway program is demonstrating the desired impact. Overall the pathway is helping students to connect their discipline studies with professional practice in order to apply engineering to complex contexts and work alongside other disciplines and professions. It appears that the focus on a specific application area of interest to students is helping to strengthen the connection between depth and breadth, rather than simply balancing breadth skills on deep discipline and hoping they bond.

C. *New Program Design*

Based on the evaluation of the pilot here, the concept of application domain pathways is being extended across the entire degree program. Multiple application pathways, or streams, will run in parallel, embedded in existing project-based core courses. These will be introduced in the first year compulsory introduction to engineering course, with application streams commencing in second year. As shown in Fig. 2 for three potential streams and certificate frameworks, students can choose to focus on a single stream throughout second, third and fourth year, or move between streams.

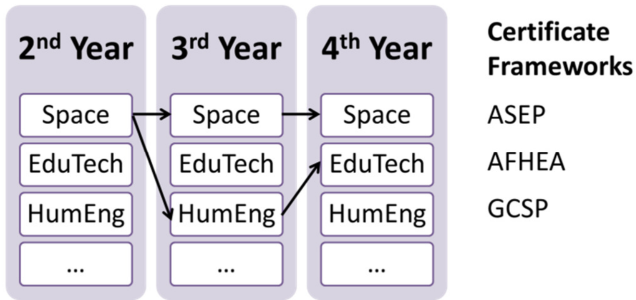


Fig. 2. Program design weaving applications streams through second to fourth year, with students able to follow a specific application pathway potentially leading to externally recognized professional certificates, or change between them.

Application streams will be proposed and championed by academics, other parts of the university, external partners, or link to student challenges and competitions. These act as the client and connect the students within the stream to relevant expertise and application contexts. Engaging students across multiple years allows for longer-term projects and partnerships to be established. Students in second year may engage in a stream in a small way, with the level of external engagement as well as student expertise in the area building to fourth year. Suggested initial application streams include space (linked to rocketry competitions), solar cars (linked to the bi-annual solar car challenge in Australia), agri-technology, accessibility, defense, educational technology, and sustainable cities.

Streams enable an application cohort, effectively a community of practice, to be built around the application domain. These consist of students from second to fourth year in the stream as well as the champion and academic convener. This promotes engagement between students in different years, as well as transfer and hand-over of ongoing projects to incoming students. It allows the entire student cohort to be divided in multiple ways; by year, by discipline major, or by application stream.

To support a broader range of application domains, further certificate frameworks are being considered for streams or the program as a whole. These include the INCOSE (International Council on Systems Engineering) Associate Systems Engineering Professional (ASEP) certification, for either the whole program or defense and space applications, and Associate Fellow of the Higher Education Academy (AFHEA) which aligns with streams around organizational change, learning, and educational technology.

This model will be rolled-out with a new incoming cohort of first year students starting in 2019. It will be supported by additional curriculum enhancements including online learning modules and content blocks for specific tools that can be learnt in a just-in-time approach. In this way, individual personalized learning pathways are constructed by students based on their interest and combination of discipline major, application stream and professional framework. This approach does not require a redesign of the entire degree program. It takes a systems integration approach, bringing existing frameworks and new material in at key intervention points, making the overall implementation and adoption, by both staff and students, less complex.

By more holistically weaving discipline depth and application breadth over the four years of a students' program, greater connections between the two are made. From the findings of the pilot pathway, early exposure to the application of engineering in an area of interest to students is helping to create a stronger bond between depth and breadth. Conceptually this is moving from a "T" (uppercase t) to a "ƚ" (lowercase t) where the intersection of breadth and depth is at the center of a student's program, expanding out in all directions, rather than just balanced on top and not combined. The intersection is moved lower, corresponding to earlier in a students' program.

VII. CONCLUSION

A pilot pathway focusing on a specific application of engineering embedded across four years of an undergraduate engineer degree has contributed to the development of T-shaped graduates. The focus of the pathway on a domain application of interest to students, combined with the inclusion of a range of for-credit and extra-curricular activities, motivated students and helped them connect their discipline depth with professional and cross-discipline breadth skills. The pathway also contributed to graduates being recognized through an external professional certification framework.

Based on the pilot, a new program design is being introduced which integrates discipline majors, application streams in project-based core courses, and professional certificate frameworks. This enables students to graduate with both a university qualification and a professional certificate to demonstrate their discipline depth and professional breadth, aligning with models of T-shaped graduates and support greater employability. This does not require the redesign of the entire engineering degree, but rather integrates existing experiences and frameworks into core project courses. The program design supports individual learning journeys for students based on their choices of discipline and applications.

APPENDIX

TABLE VI

INTERVIEW PARTICIPANT DETAILS AND UNDERGRADUATE HUMENG EXPERIENCES COMPLETED.

Pseudonym or Anonymous	Gender ^	EfaHC	Study Abroad	Final Year Project *	Extra-Curricular Activities	Cross-Disci-plinary Course	EWB Chall-enge
Anonymous	M	Y		I			Y
Anonymous	F	Y			Y		Y
Anonymous	M		Y	T			Y
Alex	M		Y	I	Y	Y	Y
Ben	M		Y	I	Y		Y
Carol	F	Y	Y		Y		Y
Charles	M	Y	Y				Y
Christiana	F	Y		I			Y
Dalia	F	Y	Y	I		Y	Y
Frank	M			I			Y
Fred	M	Y	Y	I	Y		Y
George	M	Y	Y	I	Y		Y
Jacinda	F	Y	Y	I		Y	Y
Janet	F		Y	I			
John	M	Y	Y	I			Y
Karen	F	Y	Y	I		Y	Y
Kelly	F	Y	Y	I		Y	Y
Laura	F	Y	Y	I	Y		Y
Lee	M	Y	Y	I			Y
Robert	M			I			Y
Tom	M	Y	Y	I			Y

^ F is female, M is male
* I is Individual project, T is Team project

ACKNOWLEDGMENT

The first author would like to thank and acknowledge all the students who completed surveys and took part in interviews and shared their stories about the programs outlined here.

REFERENCES

[1] NAE, "Educating the Engineer of 2020: Adapting Engineering Education to the New Century," Washington, DC: The National Academies Press, 2005.
[2] I. Flower, "The work of engineers for overseas development in humanitarian aid," *Proceedings of the Institution of Civil Engineers - Civil Engineering*, vol. 169(5), pp. 41–48, 2016.
[3] B. Allenby, "Rethinking engineering education," *IEEE International Symposium on Sustainable Systems and Technology (ISSST),* pp. 1-5. IEEE, 2011.

[4] A. Hall, and P. Childs, "Innovation design engineering: non-linear progressive education for diverse intakes," *International Conference on Engineering and Product Design Education 2009*, 10 and 11 September, pp. 1-6, University of Brighton, UK, 2009

[5] S. Uhlenbrook and E. de Jong, "T-shaped competency profile for water professionals of the future," *Hydrology and Earth System Sciences* vol. 16(10) pp. 3475-3483, 2012

[6] B. Boehm, and S. K. Mobasser, "System thinking: Educating T-shaped software engineers," *Proceedings of the 37th International Conference on Software Engineering*, vol. 2, pp. 333-342, IEEE Press, 2015.

[7] S. Kinash, and L. Crane, "Supporting graduate employability from generalist disciplines through employer and private institution collaboration: final report 2015," final report prepared for the Australian Government, Office for Learning and Teaching, Sydney, NSW, 2015.

[8] D. K. Gattie, N. N Kellam, J. R.Schramski, and J. Walther, "Engineering education as a complex system," *European Journal of Engineering Education*, vol. 36 (6), pp. 521–535, Dec. 2011.

[9] K. Lowden, S. Hall, D. Elliot, and J. Lewin, "Employers' perceptions of the employability skills of new graduates," London: Edge Foundation, 2011.

[10] A. Bielefeldt, K. Paterson, C. Swan, O. Pierrakos, D. O. Kazmer, and A. Soisson, "Spectra of learning through service programs," *120th ASEE Annual Conference and Exposition*, Atlanta, June 2013.

[11] A. Bielefeldt, K. Paterson, and C. Swan, "AC 2009-1972: Measuring the impacts of project-based service learning," American Society for Engineering Education, 2009.

[12] K. Litchfield, A. Javernick-Will, and A. Maul, "Technical and professional skills of engineers involved and not involved in engineering service," *Journal of Engineering Education*, vol. 105(1), pp. 70–92, 2016.

[13] I. Oskam, "T-shaped engineers for interdisciplinary innovation: an attractive perspective for young people as well as a must for innovative organizations," *37th Annual Conference Attracting student in Engineering*, July 1-4, 2009.

[14] K. Litchfield, and A. Javernick-Will, "I am an engineer AND: A mixed methods study of socially engaged engineers," *Journal of Engineering Education and Practice*, vol. 104(4), pp. 393-416, 2015.

[15] J. Smith, B. Anderson, N. Brown, A. Colley, A. Stoakley, and J. Turner, "The rise of humanitarian engineering education in Australasia," *28th Annual Conference of the Australasian Association for Engineering Education (AAEE1017) Order of Proceedings*, Manly, NSW, 2017.

[16] R. Watts, J. Smith, and A. Thomson, "The design and installation of Solar Home Systems in rural Cambodia," *Journal of Humanitarian Engineering*, vol. 4(2), 2016.

[17] N. Greet, "Building a humanitarian engineering network – A collaborative challenge," Collaborative Outcomes Pty Ltd Australia, 2014.

[18] L. Payne, and B. Jesiek, "Enhancing transdisciplinary learning through community-based design projects: Results from a mixed methods Study," *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, vol. 13(1), pp. 1–52, 2018.

[19] J. Smith, A. Mazzurco, and P. Compston, " Student engagement with a humanitarian engineering pathway," *Australasian Journal of Engineering Education*, vol. 23(1), pp. 40–50, 2018.

[20] NAE, "NAE Grand Challenge Scholars Program," http://www.engineeringchallenges.org/GrandChallengeScholarsProgram.aspx last accessed 29/01/2019.

[21] R. B. Johnson, and A. J. Onwuegbuzie, "Mixed methods research: A research paradigm whose time has come," *Educational Research*, vol. 33 (7), October, 2004.

[22] O. Pierrakos, R. Nagel, E. Pappas, J. Nagel, T. Moran, E. Barrella, and M. Panizo, "A mixed-methods study of cognitive and affective learning during a sophomore design problem-based service learning experience," *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, Fall, pp. 1–28, 2013.

[23] A. R Nassar, K. Holmes, and K. Mehta, "Student outcomes of short-term international humanitarian engineering fieldwork," *Frontiers in Education Conference (FIE)*, IEEE pp. 1–9, 2016.

[24] J. Creswell, " Research design: Qualitative, quantitative, and mixed-method approaches," 2nd edition, Sage Publications, California, 2003.

[25] J. Smith, J. Turner, N. Brown, and J. Price, "Integration of a short-term international humanitarian engineering experience into engineering undergraduate studies," *ASEE 123rd Annual Conference and Exposition*, New Orleans, LA, June 26-29, 2016.

[26] J. Smith, J. Turner, and P. Compston, "Student impacts of a humanitarian engineering education pathway on student learning and graduate outcomes," *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, to be published.

Chapter 9: The Rise of Humanitarian Engineering Education in Australasia

Foreword

This Chapter provides a conference paper demonstrating the increase in interest from universities and students in Humanitarian Engineering Education (HumEngEdu) in Australasia over the period of this research. The Chapter places the findings and outcomes from this study into the field of Humanitarian Engineering (HumEng) in Australia and New Zealand. Whereas Chapter 2 provided a review of education programs in HumEng and related areas globally, this article gives an overview and history of HumEng education in Australia including the use of the term, key programs, and recent growth. Particular emphasis is given to Engineers Without Borders Australia (EWB-A) and the three national education programs it delivers. A summary of each is given along with the number of universities and students engaging with them since 2007. The current and future status of programs, initiatives and courses at universities most engaged with HumEng education in Australasia is presented to give an overview of the current status of the area.

This Chapter provides a benchmark for the second and third research questions, to compare findings from the overall research to similar activities in Australasia. The data on engagement with HumEng education highlights the recent growth since 2015, which was the year this research commenced. By providing this overview and highlighting the rapid growth, the relevance of this overall study is demonstrated. The curriculum development undertaken in the first year of this research was the first of its kind in Australasia, and has been used as the basis for many of the courses and initiatives that have emerged since 2015. This highlights the significance of the data collection and analysis undertaken here (as well as to disseminate findings regularly via publications), to capture the growth of HumEng education and to understand the students who engage with it along with outcomes and challenges they face.

The publication was developed as part of a focus session on *Integrating Humanitarianism in Engineering Education* at the 2017 Australasian Association for Engineering Education (AAEE) Conference of which the author was a co-proposer and co-convenor. The paper was presented as the first in the focus session, to provide an overview of the area from which others papers focused on specific areas, initiatives or institutions.

The Rise of Humanitarian Engineering Education in Australasia

Jeremy Smith[a]; Bianca Anderson, Nick Brown, Alanta Colley, Alison Stoakley[b], and Jennifer Turner [c].
The Australian National University[a], Engineers Without Borders Australia[b] , Swinburne University of Technology[c]
Corresponding Author Email: jeremy.smith@anu.edu.au

SESSION S3: Integrating Humanitarianism in Engineering Education

CONTEXT Since the early 1980's, numerous organisations seeking to utilise engineering to address humanitarian and development challenges have been established including Engineering for Change, Engineers Against Poverty, Engineers for Overseas Development and national Engineers Without Borders and RedRs. This has contributed to the growth of humanitarian engineering education programs and initiatives in countries including the USA, UK and Canada from the early 2000's. Similarly, humanitarian engineering education courses and initiatives have been established in Australian and New Zealand.

PURPOSE This paper details the growth of humanitarian engineering education programs and initiatives in Australasia since 2006 leading to the current state of the field. From this opportunities for further growth and development will be identified.

APPROACH Student and university participation data drawn from national programs as well as details of current and planned university offerings is used to identify the growth in humanitarian engineering education in Australia and New Zealand. Outcomes from a collaborative cross-institutional workshop are used to identify priorities and opportunities for growth and development.

RESULTS Although isolated initiatives have been delivered under a variety of terms, the current growth of humanitarian engineering education dates back to the launch of the EWB Challenge in 2007. Since 2015 there has been a dramatic increase in the scale of offerings and engagement with the establishment of the EWB Humanitarian Design Summits and introduction of Australian Federal Government support for mobility programs. This has led to the development of elective courses in the area and formal award programs emerging from 2016, with at least five Australasian universities offering or planning award programs. Broader impact is demonstrated by student demographic data which clearly indicates a significantly higher percentage of female engagement in the area than typical for engineering.

CONCLUSIONS Opportunities exist to continue to expand the field and its impact including educational research and development, engagement with professional bodies, and advocacy. This will contribute to leadership and the potential for humanitarian engineering to achieve positive impacts for communities and individuals in Australasia and internationally.

KEYWORDS Humanitarian engineering, development engineering, graduate outcomes

Introduction

The role of engineering in national development and providing benefits to society has been articulated since the first civilian professional associations began in the early 1800's (Institute of Civil Engineers, 2017). The engineering profession has sought to bring these benefits to various short- and long-term humanitarian interventions as part of the growth of coordinated responses and international development since the 1960's (Lucena and Schneider 2008). From the early 1980's this led to the establishment of dedicated organisations utilising engineering to address humanitarian and development challenges including Engineering for Change (EfC), Engineers Against Poverty (EAP), Engineers for Overseas Development (EOD), national Engineers Without Borders (EWB) and RedRs (UNECSO 2010). These organisations work across the humanitarian spectrum, from immediate disaster response, through recovery and stabilisation, to long-term community and infrastructure development, disaster planning and preparedness, and capacity building (Greet 2014).

Many of the engineering organisations working in development were established by engineering students or university staff. This has contributed to the growth of humanitarian engineering education programs and initiatives in countries including the USA, UK and Canada, which engage students in the area and prepare them for future roles (Lucena and Schneider 2008, UNECSO 2010). In Australasia, individual courses and initiatives within humanitarian engineering education were established in the early 2000's and have been growing since 2007.

This paper reviews the integration of humanitarianism in engineering education in Australasia and details the growth of humanitarian engineering education programs and initiatives since 2006. It first discusses humanitarian engineering including a working understanding of the term and overview of some of the key organisations. Data on university and student engagement is provided from national programs and university offerings. Finally, opportunities, challenges and priorities for continued growth and support are identified.

What is humanitarian engineering?

The term *humanitarian engineering* (HumEng) only emerged in Australasia with Engineers Australia's, the peak professional body, *Year of Humanitarian Engineering* in 2011. Prior to that, terms such as *development engineering* were used (Turner et al. 2015). The first reference to the term at an Australasian Association for Engineering Education (AAEE) conference was in 2013, previously *EWB* was used as a synonym for the field.

The understanding of HumEng that has emerged in Australia since 2011 encompasses a wide range of contexts and locations, from disaster response through to community and technology development, both internationally and domestically. HumEng is taken as the application of an engineering discipline, such as civil or mechanical, to a specific humanitarian or development context or response. In this way, it is an application area requiring additional dedicated knowledge, skills, attitudes and competencies rather than a unique discipline. This is a broader understanding than other countries, for example in the USA HumEng encapsulates predominately non-US development while in the UK it focuses on disaster response and recovery. (Turner et al. 2015)

While there has always been individual *humanitarian engineering education* (HumEngEdu) offerings available to students, the first structured programs providing multiple engagements emerged from universities in the USA in the early 2000's (Bixler et al. 2014, Dean and Van Bossuyt 2014). In Australasia, a small number of not-for-profit organisations have been leading the development of education and training initiatives in the area. RedR Australia was established in 1992 to make engineering available to disaster relief and has since expanded to offer expertise across all aspects of humanitarian emergencies (RedR Australia 2017). RedR has offered short-course professional development training since 1998 and has recently expanded to support tertiary education and as of mid-2017 has partnerships with five Australian universities across a range of humanitarian response aspects, not only engineering (RedR Australia 2017).

The first wide-scale HumEngEdu offerings in Australasia were developed by Engineers Without Borders Australia (EWB-A). EWB-A, which was established as an independent national organisation in 2003, has a focus on community development in Australia and the surrounding region. EWB-A delivers three programs (discussed below) targeting tertiary education. Engineers Without Borders New Zealand (EWB-NZ), another independent national EWB organisation, established in 2008, provides three programs to universities in NZ. Since 2016, further offerings have emerged in Australasia. The first Australian chapter of Engineering World Health (EWH), a US-based organisation to improve healthcare delivery in low-income countries, operates at the University of New South Wales (Engineering World Health 2017). The Laika Academy provides short-term study abroad opportunities covering topics interfacing with HumEng including design for social change, sustainable development, social enterprise and community rebuilding (Laika Academy 2017).

Humanitarian engineering education in Australia and New Zealand

The opportunities provided by external organisations are incorporated into universities programs as institutions deem appropriate. Universities expand on those to develop their own opportunities depending on resources, expertise and demand. However, the largest programs, in terms of duration and reach, are those offered by EWB-A which are detailed below. Data from the EWB-A programs combined with a summary of university courses and programs, will be used to investigate the overall scale of HumEngEdu in Australasia. While this data will not be comprehensive, it will provide an indication of growth and overall trends.

The EWB Challenge

The EWB Challenge, coordinated by EWB-A, is a design program delivered in partnership with universities which introduces concepts of humanitarian engineering to students in addition to crowd sourcing ideas for community based organisations. Each year the EWB Challenge focuses on projects identified in conjunction with one of EWB-A's community based partner organisations. The EWB Challenge provides a platform that enables universities to meet learning outcomes associated with global citizenship, professional practice and sustainability. Universities embed the EWB Challenge into first year engineering curriculum, typically within an introduction to design or engineering unit, adapting the program to meet the learning outcomes of the unit in which it is embedded.

The EWB Challenge has arguably been the most influential program contributing to the rise of HumEngEdu in Australasia. The EWB Challenge was introduced at a time of increased pressure to renew first year engineering curriculum and adopt education pedagogies such as project based learning to meet changing education demands (Jolly 2014). The EWB Challenge provided real world project briefs and supporting resources, such as data, photographs and report marking criteria, making it appropriate for universities to embed. The EWB Challenge provided a common platform for universities to compare and evaluate their approaches to first year engineering education as seen in a 2014 Office of Learning and Teaching report by Jolly (2014):

> "The Challenge is unique [at the time of the evaluation] for engineering in that, like some approaches in medicine, agriculture and elsewhere, it has a strong and distinctive focus on the development of graduate attributes related to social, cross cultural and ethical responsibilities in a global context." (Jolly 2014)

The EWB Challenge was launched as a national program in 2007 in partnership with 21 universities and reached approximately 3,500 students, see Figure 1 A). It rapidly expanded and in 2017 reached 9,040 students at 28 universities including the off-shore campuses of Australian institutions, and remains the largest HumEngEdu initiative in Australia and New Zealand. In 2011 the EWB Challenge program was introduced to the UK where the program, referred to as the Engineering for People Design Challenge, is co-ordinated by Engineers Without Borders UK (EWB-UK). In 2016/2017 this reached 4,600 students across 23 universities (EWB-UK, 2017). The EWB Challenge was supported by university registration fees subsidised by sponsorship from BHP Billiton Sustainable Communities from 2008 to 2015. Since then the program has been funded solely by university registration fees.

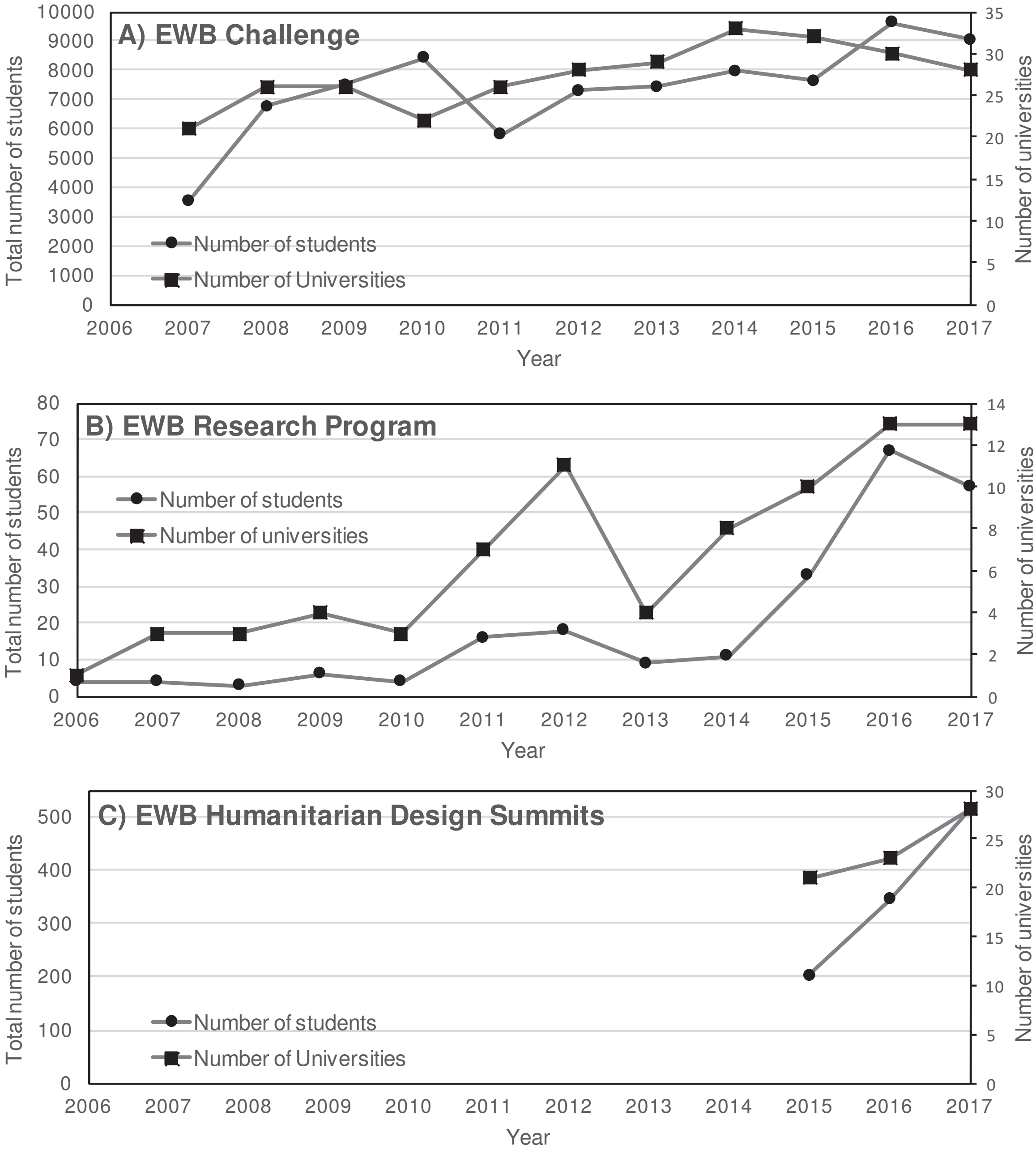


Figure 1: Total number of students and universities in Australasia participating in A) the EWB Challenge, data supplied by EWB-A from university registrations where universities self-report student numbers, B) the EWB Research program, data supplied by EWB-A from student registrations and C) the EWB Humanitarian Design Summits, data supplied by EWB-A from student registrations. (Note: data for 2017 is estimated)

EWB University Research Program

The EWB University Research Program, established by EWB-A in 2006, engages students, academics and community organisations in collaborative research projects. Beyond the development of new humanitarian knowledge and technologies, the program provides university students with an opportunity to grow humanitarian skills and social impact motivation before entering the workforce. The real-world context is vital with all projects targeting opportunities identified by practitioners and community development organisations working towards sustainable development in the Asia-Pacific region. The EWB University Research Program has conducted over 200 collaborative research projects in total as shown in Figure 1 B). In 2017, the program was delivered in partnership with 13 universities engaging 57 undergraduate researchers. The program was initially run through volunteer support while since 2009 the program management has been part of a paid role. A similar program is supported by EWB-NZ targeting universities in NZ.

EWB Humanitarian Design Summits

The EWB Humanitarian Engineering Design Summit program is a short-term study aboard opportunity designed to provide students with an experience to develop a deeper understanding of the role design and technology plays in creating positive change within communities. Students work through a human-centred design cycle over two weeks culminating with presentations of ideas to community members and organisations. A key component of the learning is ensuring that students participate in a genuine, immersive rural experience with a community. To deliver the program EWB-A partners closely with local grass-roots organisations that have a working relationship with communities.

The program was inspired by the hands-on International Development Design Summit at Massachusetts Institute of Technology's (MIT) D-Lab, leaders in human-centred co-design and community creative capacity building. Recognising the need for professional practice training and building on the experience of EWB's previous pilot study-tours, the Humanitarian Design Summit was launched 2015. The program has expanded to deliver 12 programs a year in six countries and has a network of over 800 alumni with university and student participation shown in Figure 1 C). The program collaborates with more than 25 Australian universities and is recognised through the Australian Government New Colombo Plan. EWB-NZ also runs similar opportunities for New Zealand university students.

Measured learning outcomes for students include development of personal and professional skills, application of knowledge in a development context, recognition of development practices and use of human-centred principles. The program delivers outcomes through workshop sessions, cultural immersion activities and student-led investigations. The program includes Academic Fellow positions allowing university staff to participate and gain first-hand experience in humanitarian contexts, which they can utilise within their teaching practice (Brown et al. 2016).

University humanitarian engineering offerings

Current and planned HumEngEdu course and program offerings from a range of Australasian universities are shown in Table 1. This is not intended to be a complete list and is provided from institutions involved with the Humanitarian Engineering Education Network of Australasia (described below). It focuses on university level tertiary education only, excluding the VET sector and professional development. This includes the two currently available award programs at the University of Canterbury and the University of Sydney.

Most of the universities engaged with HumEngEdu, shown in Figure 1, are involved with more than one initiative with the overall number of universities in Australasia involved with HumEngEdu in the order of 30. This means at least 60% of the universities offering engineering in Australia and NZ are involved with HumEngEdu in some form (EA 2017, Education NZ 2017). From Table 1 at least five of these universities currently offer, or plan to offer, award programs under the term Humanitarian Engineering. All of these award programs are complementary, or added, to an existing bachelor's degree in engineering, mostly commonly in the form of a four-unit program (called a minor or major depending on institution). This aligns with the understanding of HumEng in Australasia, as the conscious application of a base engineering discipline to humanitarian contexts or responses.

Table 1: Selection of humanitarian engineering education university offerings, including current status of proposed or planned programs

University	Offering	Structure	Status / notes
The Australian National University	Master of Humanitarian Engineering	Proposed vertical double degree with a Bachelor of Engineering.	Proposed, if approved would be available from 2019 to all engineering students.
RMIT University	Elective course in Master of Engineering	12-credit point, first year dedicated humanitarian engineering elective	Currently offered.
Southern Cross University	Compulsory course in Bachelor of Engineering	12-credit point, first year compulsory course.	Focuses on a humanitarian engineering project (independent of the EWB Challenge).
Swinburne University of Technology	Social Impact Pillar and compulsory service learning in Bachelor of Engineering Practice	Social impact is one of 4 compulsory pillars. 15% of student workload is dedicated to service-learning project work.	Bachelor of Engineering Practice commences in 2018 and integrates social impact across the degree rather than a separate focus.
The University of Adelaide	Minor in Humanitarian Engineering	Six courses, 2 as double-badged, 4 dedicated courses from a list of 7.	Approved to commence in 2019 available to all engineering students.
University of Canterbury	Diploma in Global Humanitarian Engineering	Mix of cross-credit courses, non-engineering electives and capstone course	Commenced in 2016.
The University of Melbourne	Minor in Humanitarian Engineering	Within the 2-year Master of Engineering.	Proposed, if approved would be available from 2019 to all engineering students.
The University of New South Wales	Courses in Humanitarian Engineering	Two new humanitarian engineering focused courses.	To commence 2018, available to all engineering students.
The University of Sydney	Major in Humanitarian Engineering	Four compulsory courses (3 engineering, 1 arts).	Commenced 2017, first graduates expected 2018, available to all engineering students.
University of Wollongong	Scholars Research Project	6-credit unit course.	Students undertake field work in Rwanda.
University of Technology Sydney	Summer Intensive Design Studio	Design studio focused on humanitarian engineering.	To be offered for the first time in the 2017/18 summer session.

Impacts of humanitarian engineering education

The growth of HumEngEdu has already had impact on engineering education and professional practice in a number of positive ways. One of the strengths of HumEngEdu is a greater level of engagement of female students. Female participation in the EWB University Research program since 2006 is 38% while the female participation in EWB Humanitarian Design Summit since being recorded from mid-2016 is 45% (data supplied by EWB-A). Female applicants make up 41% of the total EWB Humanitarian Design Summit applications, suggesting female applicants are more likely to be accepted as they are of higher quality and articulate stronger motivation statements. These compare to female participation of 12.4% of the engineering workforce and the 15-20% common in undergraduate engineering studies (Engineers Australia, 2017). Similar trends are seen at individual institutions, for example at the ANU female participation in optional or elective HumEngEdu since 2007 is 33% compared to an overall female participation of 22% (data supplied by ANU).

Another strength of HumEngEdu is its alignment with recent changes to the portrayal of engineers and additions to Engineers Australia's strategic plan and purpose. To the purpose in their previous strategic plan (2014/15 - 2016/17), "*We are the global home for engineering professionals renowned as leaders in shaping a sustainable world*", the 2017/18 - 2019/20 strategic plan has added *"Engineers Australia shapes the future of Australia - creating happy, healthy, prosperous and sustainable communities*" along with a strategy to "*advance the science and practice of engineering for the benefit of the community*" (EA, 2017a).

Across the growth of HumEngEdu a number of limitations and challenges have been encountered. One of these, the cost of participating in immersive study experiences such as EWB Humanitarian Design Summits, has been eased through the Australian Federal Government New Colombo Plan (NCP) scholarships. Launched in 2014, these are designed to support experiences in the Indo-Pacific and have certainly contributed to the growth of programs offered by EWB-A and the Laika Academy. However, NCP scholarships are limited to domestic students and may still leave a significant funding gap for some students.

As highlighted in international research (such as VanderSteen et al. 2009), another challenge is the ethics and appropriateness of students engaging in development and community work. This must continuously be considered, in particular in relation to resources committed and outcomes received by the parties involved. Considerations are taken into account through the design of programs, with students in the EWB University Research Program and EWB Humanitarian Design Summits only engaging in development through scaffolded and mentored experiences and not independently leading a project. The understanding of HumEng within Australasia emphasises not only international work, as in some countries, but highlights domestic development challenges and inequities.

An early challenge in HumEngEdu in Australasia was the expertise of academics and educators, with many coming from engineering backgrounds with little or no development experience. The Academic Mentor roles within EWB Summits were designed with this in mind, to provide field experience, while further capacity is being built through annual EWB Challenge academic workshops, dedicated HumEng academic positions, the establishment of network of educators (see below) and the expertise provided by EWB-A and RedR.

Opportunities and recommendations for the future

To support the growth of HumEngEdu, the Humanitarian Engineering Education Network of Australasia (HEENA) was formed at the start of 2017. Involving more than a dozen universities this serves as a platform for academics, educators and practitioners involved with HumEngEdu initiatives to support one another, build on strengths and overcome limitations. In September 2017, this network held a half-day discussion exploring the growth of HumEngEdu, attended by eight Australian universities and two education providers. From this discussion, a number of priority areas were identified to support growth and delivery of programs at individual institutions, continue cross-institutional collaboration, and demonstrate national leadership. The priority areas identified were:

1. The establishment of a national Advisory Board to provide advocacy, leadership and engagement for the further growth and development of HumEng.
2. Engagement with EA to ensure alignment of HumEng education, professional development and practice with EA structures, recognition and processes.
3. Education design and delivery, including the development and sharing of course material, curriculum approaches and education research. This will seek to build an evidence base to evaluate the impact of HumEngEdu on graduate employability and partners to support continuous improvement and best practice.
4. Research and funding, to support research and development in the area and opportunities for collaborations to support broader impact beyond education.

Many of these aims build on existing work in the area in Australia (such as Greet 2014, Smith et al. 2015, Turner et al. 2015) and internationally (for example Bixler et al. 2014, Dean and Van Bossuyt 2014, VanderSteen et al. 2009). They recognise that work and education in humanitarian contexts is highly complex and multi-disciplinary. In most cases, it involves engagement and work with potentially vulnerable and at risk individuals and communities requiring the highest level of ethical practice and conduct. A shared understanding of HumEng and its application is required to enable appropriate delivery of education, research, services and impact, which is a focus for HEENA. This will promote further growth aligning with the newly articulated purpose of EA and to create a new generation of engineers able, and willing, to emphasis positive community benefits in all engineering work.

Conclusions

Ten years after the wide-scale introduction of the EWB Challenge and EWB University Research Program, HumEngEdu is now common across universities in Australia and NZ. There has been a step-change in the integration of humanitarianism into engineering education since 2015 with at least 60% of universities in Australasia offering engineering involved in HumEngEdu in some form, two currently delivering award programs and at least three more planning award programs. This increase has been driven and supported by student interest, a recognition of the global nature of engineering, and new opportunities for students to be involved in study abroad programs. The increase has demonstrated impacts on gender diversity in engineering education with programs and initiatives typically reporting 50% or higher female participation than on average.

A network has been established by universities and organisations working in HumEngEdu to support its continued growth. This has led to priority areas being identified for further collaborations, discussions and leadership to ensure HumEngEdu is delivering on its potential to support student outcomes and achieve positive impacts for communities and individuals in Australia, NZ and internationally.

References

Bixler, G., Campbell, J., Dzwonczyk, R., Greene, H. L., Merrill, J., and Passino, K. M. (2014). Humanitarian engineering at the Ohio State University: Lessons learned in enriching education while helping people. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship,* (S.I.), 78-96.

Brown, N., Price, J., Turner, J., and Colley, A. (2016). Professional development within study abroad programs for engineering educators to gain confidence in preparing students to contribute to the Sustainable Development Goals *27th Annual Conference of the Australian Association for Engineering Education (AAEE2016) Order of Proceedings*

Dean, J. H., and Van Bossuyt, D. L. (2014). Breaking the tyranny of the semester: A phase-gate sprint approach to teaching Colorado School of Mines Students important engineering concepts, delivering useful solutions to communities, and working on long time scale projects. *International*

Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship, (S.I.), 222-239.

Education New Zealand (2017). *Education New Zealand.* Available from www.studyinnewzealand.govt.nz Last accessed Sep25, 2017,

Engineering World Health (2017). *Engineering World Health.* Available from www.ewh.org Last accessed Sep11, 2017

Engineers Australia (2017). The State of the engineering profession: Engineering in Australia. *Engineers Australia*

Engineers Australia (2017a). Our strategic direction 2017/2018 – 2019/2020. *Engineers Australia.*

Engineers Without Borders Australia (2017). EWB organisational strategy 2015. *Engineers Without Borders Australia*. Retrieved Sep 11, 2017, from www.ewb.org.au/explore/initiatives/chaptercollaborationteam/orgstrat

Engineers Without Borders UK (2017). Engineering for People Design Challenge. *Engineers Without Borders UK.* Available at www.ewb-uk.org/engineering-for-people/ last accessed Sep 27, 2017.

Greet, N. (2014). Building a humanitarian engineering network – A collaborative challenge. *Collaborative Outcomes Pty Ltd Australia*

Institution of Civil Engineers (2017). Our History. *Institute of Civil Engineers.* Available from www.ice.org.uk/about-ice/our-history Last accessed Sep 11, 2017.

Jolly, L. (2014). Curriculum renewal in engineering through theory-driven evaluation. *Office for Learning and Teaching*

Laika Academy (2017). Programs. *Laika Academy*. Available from www.laikaacademy.com/programs Last accessed September 11, 2017.

Lucena, J., and Schneider, J. (2008). Engineers, development Engineers, development, and engineering education: From national to sustainable community development. *European Journal of Engineering Education*, *33*(3), 247–257.

RedR Australia (2017). *RedR Australia*. Available from www.redr.org.au Last accessed Sep11, 2017.

Smith, J., Turner, J., and Brown, N. (2015). Design for Dissemination - Development of a Humanitarian Engineering Course for Curriculum Sharing. *26th Annual Conference of the Australian Association for Engineering Education (AAEE2015) Order of Proceedings*

Smith, J., Turner, J., Brown, N., and Price, J. (2016). Integration of a short-term international humanitarian engineering experience into engineering undergraduate studies. *American Society for Engineering Education's (ASEE) 123rd Annual Conference and Exposition*

Turner, J., Brown, N., and Smith, J. (2015). Humanitarian Engineering – What does it all mean? *26th Annual Conference of the Australian Association for Engineering Education (AAEE2015) Order of Proceedings*

UNESCO (2010). Engineering: issues, challenges and opportunities for development. Paris: *UNESCO Publishing.*

Vandersteen, J. D. J., Baillie, C., and Hall, K. (2009). International humanitarian engineering. *IEEE Technology and Society Magazine*, 28(4), 32–41.

Acknowledgements

The authors wish to thank all those educators, practitioners and academics who provided input, data and suggestions into the development of this paper, and in particular all those involved with HEENA for their time, commitment and enthusiasm.

Chapter 10: Conclusion to Study

This conclusion draws the findings from the individual chapters together and specifically addresses the research questions and aims in Chapter 1. The impact and dissemination of research and findings is outlined, considering both the local context of the ANU and Australasia. Impacts for engineering practice and education, particularly with respect to diversity and the role of engineers, is highlighted. Limitations of the methodology used and thesis approach are discussed along with planned and potential research for the continuation of work at the ANU and elsewhere. Finally, a personal reflection on the research and its outcomes is provided.

10.1 Summary of Findings

Chapter 1 set three research areas, which are repeated below.

1. *Curriculum* approaches necessary for Humanitarian Engineering Education (HumEngEdu):
   1.1. What curriculum approaches can achieve outcomes for HumEngEdu?
   1.2. What combination of curriculum approaches are required for HumEngEdu programs and pathways?
2. *Student engagement* with HumEngEdu:
   2.1. Which HumEngEdu initiatives and experiences do students engage with and when in their studies?
   2.2. What are the key motivations for students to engage with HumEngEdu?
   2.3. What is the profile of students that engage with HumEngEdu?
   2.4. How does the profile of students engaging with HumEngEdu compare to a broader engineering student cohort?
3. *Outcomes* for students from their engagement with HumEngEdu:
   3.1. What knowledge and competencies for Humanitarian Engineering (HumEng) are students achieving?
   3.2. How do students integrate HumEng with the rest of their studies?
   3.3. What other outcomes are being achieved by students through their engagement with HumEngEdu?

The key findings for each area are summarised below, drawing together results from across individual chapters and the mixed-methods study.

10.1.1 Curriculum Approaches

This research built from existing work, particularly in the US, on the range of curriculum approaches used for Humanitarian Engineering (HumEng) Education (HumEngEdu). Chapters 2-4 identified study-abroad, project-based learning (PBL), service-learning (SL), and intensive teaching mode as approaches that can achieve outcomes for HumEngEdu. PBL was already in place in the engineering degree at the ANU before this research commenced, with the EWB Challenge in first year, individual and group projects in final year, and opportunities for smaller projects and assignment topics in second and third year (EWB-A initiatives are outlined in Chapters 6 and 9). New study-abroad and intensive teaching mode experiences were designed and implemented as part of the research, including the creation of the Engineering for a Humanitarian Context (EfaHC) course. As detailed in Chapter 3, this was developed using an adaptation of the systems engineering Vee-model in order to provide flexibility in the teaching mode so it could be delivered as either a traditional semester course or in an intensive mode. As discussed in Chapter 5, the latter was chosen for two reasons: to build a cohort and community in the course; and to enable short-term study-abroad experiences to be incorporated into the course.

Overall, while it was found that many of the pedagogical approaches utilised in existing programs overseas were appropriate for this work (based in Australia), a specific curriculum (as a combination of pedagogy, teaching approaches and context) did need to be developed. This supports the assumption from Chapter 1 that existing curriculum from overseas cannot be delivered in Australia in the same way. Local curriculum is required particularly for content, even though lessons can be drawn for pedagogy and delivery approaches. In the case of the EfaHC course content was incorporated on Australia's specific humanitarian and development context to ensure its relevance and appropriateness for students and graduates. As highlighted in Chapter 1, this included Australia's history, both pre- and post-European settlement, and a history of international development in Australia - particularly Federal Government policy and structures, indicators of domestic disadvantage and vulnerability in Australia, Aboriginal and Torres Strait Islander knowledge systems and engineering, and the National Disability Insurance Scheme (NDIS). Full details of the topics and structure of the course and its development are available through the final report submitted to the Office for Learning and Teaching (Smith et al 2015).

In parallel to the intensive mode EfaHC course, a range of study-abroad options made available to students. These included short-term study-abroad experiences and travel linked to final year research projects. A number of potential ways to integrate experiences to provide flexibility to students were explored and the strengths and weaknesses of different approaches evaluated. Common short-term experiences, typically 10-14 days, were the EWB Humanitarian Design Summits (which started in 2015), Enabled Futures (commenced 2016), and Unbound (commenced 2016, initially called Laika Academy). These were guided experiences in which typically 20-40 students from multiple universities supported by a team of 4-8 facilitators explored elements of engineering practice or development. Experiences for individual students were undertaken, typically placements with NGOs and social enterprises, both domestic and international. Curriculum integration methods included course-credit (specifically within EfaHC), as part of a research project, or to contribute to work experience requirements.

Chapter 3 suggested an intensive delivery mode for EfaHC in order to align with short-term study-abroad experiences and to build a learning community for the course and its focus. Chapter 3 provided evidence of the benefit of this approach for the inclusion of EWB Summits (and later other opportunities). Chapter 5 provided further evidence of the advantage of the selected delivery mode to support the development of an identified threshold capability to incorporate social factors into engineering design.

As described in Chapters 4, 5 and 7, it was found that incorporating short-term experiences in EfaHC generated the greatest learning for students from the alternatives available. This was due to the structured curriculum for the experience, including workshops, reading and assignments before the travel, and workshops and assessment after. In particular, the scaffolded post-workshops and reflection-based assignments required students to reflect on their experience, identify key learnings, and link the experience to the rest of their engineering studies. Coming from the analysis in Chapter 7, individual experiences were found to be more effective in final year when part of a larger pathway, particularly when a student had completed a short-term experience earlier in their studies. In this case students had a relevant background and more realistic expectations for their individual work.

Building from the results in Chapters 4 to 7, particularly the three pathways identified and Table 9 from Chapter 7, it was found that an appropriate combination of curriculum approaches for the HumEng pathway consisted of:

1. Early exposure to HumEng or development, which could include extra-curricular engagement.
2. PBL opportunities in existing core engineering practice courses. This effectively requires no curriculum changes.

3 A short-term intensive experience on HumEng, potentially incorporating a study-abroad experiences, in the second to third year transition.
4 An opportunity for a SL project in final year, including engagement with the external partner.
5 Cross- or multi-disciplinary courses or experiences in third or fourth year.

It was found this was the approach which enabled students to make the greatest links between their engineering studies and knowledge and HumEng. It provided early exposure to HumEng so students could make a connection to their individual motivations. From there, it progressively brought in HumEng and humanitarian action and development knowledge in parallel to the development of students' engineering knowledge. This pathway aligned with students' maturity through their university studies and provided a structured way to reflect on their experiences at keys points. Chapter 8 describes how the approach and pathway identified in this research can be being embedded across the entire engineering degree at the ANU.

The research here was supported by the natural alignment of HumEng with the systems engineering core at the ANU. Systems engineering seeks to provide tools and approaches to address complex, multi-discipline contexts and provides a focus on system boundaries, problem definition, and life-cycle considerations. As highlighted by Burnham (2009) "Humanitarian Engineering represents a maturation of the founding principles of Systems Engineering" highlighting humanitarian engineers must have technical mastery, social, political and economic understanding, and a global perspective. Many definitions of HumEng have at their core a specific engineering discipline, such as electrical or mechanical, which is then applied through a range of tools, approaches and potentially mindsets to complex humanitarian and development context. The structure of the engineering degrees at the ANU aligns with such contemporary understandings of HumEng.

10.1.2 Student Engagement

Student engagement with HumEngEdu experiences and the pathway created in response to the first research question was investigated in four areas, each summarised below. This focuses predominately on the quantitative aspects of the research, drawing particularly from Chapters 6 and 7.

10.1.2.1 Participation

Overall 8-12% of the engineering undergraduate cohort are engaging in HumEng experiences (Tables 5-7 in Chapter 6). The specific initiatives undertaken by graduates who were interviewed are provided in Tables 3 and 9 in Chapter 7 with the latter providing a detailed outline of which HumEng experiences those most involved completed. Overall, HumEng participation is predominantly through the EfaHC course, short-term study-abroad experiences, and final year individual and group research projects. However, this is not a consistent pathway with only 46% of students doing a HumEng research project taking part in a study-abroad experience (Table 10 in Chapter 6).

Involvement in short-term study-abroad experiences such as EWB Summits was enabled through scholarships, particularly the New Colombo Plan (NCP) program. From Table 8 in Chapter 6, almost 90% of those taking part were receiving scholarships, with only 42% stating they would have still taken part if they had not received one.

The majority of those taking part in dedicated HumEng experiences were in third and fourth year. This may be due to the new nature of the initiatives, with third and fourth years taking part in initiatives that were not available to them when in first and second year. From Chapter 7, many graduates stated they would have liked to take part earlier in their degree, and only came across HumEng in the later stages of their study. However, others did highlight that engagement came from a level of maturity that was potentially not present when they were in first or second year.

10.1.2.2 Student Motivations

Key motivations for students opting to undertake HumEng experiences were identified in Chapters 6 and 7. From Table 15 in Chapter 6, general motivations included travel (for international experiences) and students looking for opportunities to apply and use their engineering, regardless of the context. Also articulated were HumEng-specific motivations for an interest in the area and wanting to "help" via engineering.

It was found those engaging in HumEng had strong career motivations to work in the area. Across Table 14 in Chapter 6 (from surveys) and Table 5 in Chapter 7 (from interviews), careers in the *humanitarian response, or community, not-for-profit or social enterprise* sector were ranked first by participants from a list of 11 potential areas.

10.1.2.3 Profile

An understanding of the profile of students engaging in HumEng was captured from quantitative aspects of the study, provided in Tables 9-12 in Chapter 6 and Tables 2 and 8 in Chapter 7. Key characteristics for students engaging in HumEng were they were almost entirely domestic with English as a first language. They were typically completing a double degree, studying full-time and likely to be involved in extra-curricular activities such as student clubs and societies.

10.1.2.4 Comparison

A quantitative comparison was made between key characteristics of students engaging in HumEng activities and the overall engineering student cohort at the ANU. These are outlined in Tables 9-14 in Chapter 6 and Tables 2 and 8 in Chapter 7. A number of characteristics were found to be statistically significant between students involved with HumEng compared to the overall cohort, with HumEng students more likely to:

- Be domestic and have English as a first language.
- Have previous or current unpaid work.
- Be involved with student or university organisations.
- View professional skills and ethical practice as important for engineering practice.
- Want a career in the *humanitarian response, or community, not-for-profit or social enterprise* sector.

Other characteristics were found to vary, although not statistically significantly, and these are a focus of ongoing research both at the ANU and other institutions (see Section 10.4). Compared to the overall cohort, HumEng students more likely to:

- Come from rural backgrounds.
- Be enrolled in a double degree.
- Have taken a gap-year before starting university.
- Be female.
- Have engineering work experience.
- Have been involved with community or volunteer work before starting university.
- Work while at university.
- Commit more hours per work to extra-curricular activities and take on leadership roles.
- have been involved in a study-abroad program.

- Identify less with engineers and being an engineer is less important to how they feel about themselves.

Combined, this paints a picture of domestic student engineers undertaking a wide range of experiences beyond their studies including engineering work experience, extra-curricular activities, study-abroad, and a second degree. Students are less attached to their engineering identity, perhaps due to the prevalence of double degrees and extra-curricular activities (Tables 9-12 in Chapter 6). HumEng students value professional skills and ethical practice more highly than the overall cohort (Table 13 in Chapter 6). When considering this, as well as the range of experiences they are undertaking, they fit the model of the T-shaped graduate, as described in Chapter 8. HumEng students are completing a major in a specific discipline to provide depth, but have greater appreciation of professional skills, as well as experience of applying them, through work experience and extra-curricular activities. This is similar to findings from Litchfield et al (2016) when looking at outcomes from involvement with engineering service.

10.1.3 Student Outcomes

While outcomes from engagement with HumEng experiences were identified across Chapters 4 to 7, they are summarised through the seven outcome themes described in Chapter 7, drawing from both quantitative and qualitative data. The outcome themes are:

1. Employability.
2. Tools, processes and skills.
3. Personal beliefs.
4. Social and enjoyment.
5. Motivations.
6. Understanding of HumEng.
7. Engineering practice.

There were positive contributions from engagement in HumEng experiences in all these areas.

How students integrated HumEng elements into the rest of their studies was explored in Chapter 7, particularly Tables 3 and 9, and from the three pathways identified: isolated; integrated; and holistic. In the isolated pathway, students considered their HumEng and engineering separately, potentially not seeing connections between them. Students in the integrated and holistic pathways weaved all their experiences together. However, the students in the holistic group, who had typically undertaken multi-disciplinary studies, could articulate how HumEng and engineering influence each other to achieve positive outcomes.

Specific tools, processes and skills were developed through HumEng experiences, particularly design approaches such as user- and human-centred design. Additional benefits articulated included a sense of inclusion and community. This potentially contributes to the greater percentage of females participating compared to the overall cohort. This is captured in quotes from interviews in Chapter 7, and is similar to work in the US with students involved with EWB-USA (Litchfield and Javernick-Will 2015).

In Chapter 1 the hypothesis was set that engineering education that includes HumEng will produce more effective engineers as assessed across the full range of EA Stage 1 competencies. In other words, engaging with HumEngEdu will provide engineering graduates with skills and outcomes beneficial for all engineering practice. Across the results here, this hypothesis is considered proven from a student perspective. As stated, positive outcomes for employability in a range of engineering roles was found, with graduates feeling more employable, as well as interest shown from employers in HumEng experiences. The profile of students involved with HumEngEdu was found to fit the T-shaped graduate model of discipline depth and professional breadth, as discussed in Chapter 8. Graduates recognise the same levels of importance of technical areas, but attach greater importance to professional and ethical practice compared to the overall cohort, while undertaking a greater range of experiences while studying. All of these contribute to the EA Stage 1 competencies and are relevant for modern engineering practice.

10.2 Research Contributions

The contributions of the study and outcomes generated are discussed below. These are for education at the ANU, to the academic field and current research, and the field in Australasia.

10.2.1 Educational Outcomes

The research undertaken here has made direct impacts to engineering education at the ANU. The most obvious of these are new education experiences for students to enhance their learning. These include the EfaHC intensive course and the integration of study-abroad experiences. EfaHC was the first regular intensive course to be offered in the engineering degree at the ANU, providing a number of lessons for further courses utilising this delivery method, as outlined in Chapter 6. Through the development of the HumEng pathway, more than 100 externally funded scholarships have been secured for ANU engineering students to take part in experiences such as EWB Summits, Enabled Futures, and programs offered by Unbound.

A clearly defined impact is the creation of the new four-course Minor in Humanitarian Engineering outlined in Chapter 7. The research in this study directly shaped the design of the Minor, seeking to replicate the holistic pathway identified. This is only the third formal award program of its type in Australia. The program was approved in 2018 and commenced in 2019, the year this study was completed.

Further impacts for engineering education at the ANU have been created by abstracting the findings from this study. In particular, benefits for student learning were identified by weaving application or domain areas within the core engineering program, supported by targeted experiences such as intensive courses and the opportunities to apply engineering beyond the classroom. As outlined in Chapter 8, this approach, first demonstrated in the HumEng pathway, is being used to redevelop the compulsory core of the engineering degree at the ANU by providing a range of domain application streams. The goal is to build on motivations for the application of their engineering to help students connect this to the rest of their discipline studies. As found with HumEng, many students were seeking this opportunity, and once provided it gave them additional motivation for all of their studies, as outlined in Chapter 7. This was particularly the case for female students, and hence this approach could contribute to greater female participation across the entire engineering program. To support diversity, benefits for inclusion were identified, with many participants, particularly females, saying they found the culture of HumEngEdu experiences more welcoming and inclusive. This was often linked to being part of a group with a shared common goal or interest, as was achieved through the HumEng application focus of the pathway.

Although not a focus of the study (see *Current and Future Work* below), impacts for external groups and partners may have also occurred. These were almost entirely from final year projects, and typically those that included time spent with partner organisations. However, there were only a limited number of such projects. Positive impacts for partners in Cambodia, Laos, and Australia were identified by students during interviews, although in many cases not independently verified.

10.2.2 Academic Impacts and Research in the Field

The research undertaken here is the first of its kind in Australia. It is the first study to undertake a detailed exploration into multiple engagements with HumEngEdu to investigate the students who engage with it, and the outcomes they gain. This study advances the understanding of HumEngEdu internationally, by bringing another national perspective to the field. While there has been significant research in the area overseas, particularly the US, as highlighted in Chapter 1, the humanitarian action and development contexts and priorities for Australia are unique, as they are for all countries. Overseas research can provide input and insights, but research is required specifically for the Australian context, which is what this study contributes. As discussed in the *Current and Future Work* section, studies are now being undertaken at a number Australasian institutions, collecting similar data to here. This research developed a HumEng pathway within the Australian context and incorporates domestic development and Australian regional priorities.

The findings from this research contribute to the growing body of evidence in similar countries, such as the USA, Canada and UK, of the benefits of HumEngEdu. Echoing research from overseas, benefits for diversity and inclusion were found as well as engineering practice as a whole. This demonstrates the new and novel contributions of this study, that the development of HumEngEdu for the unique Australian context, incorporating specific national content, priorities and approaches, produces benefits for HumEng and engineering broadly.

Obviously, as a thesis by compilation, there have been numerous publications from this work, captured in Chapters 2-9. Two articles have been published in the *International Journal for Service Learning in Engineering: Humanitarian Engineering and Social Enterprise*. This is the most relevant journal for the HumEng work in this study, enabling the research to be reviewed and disseminated to the international community focusing on this area. To provide impact to the Australian engineering community, a key article was published in the *Australian Journal of Engineering Education*. Engineering education conferences in the US and Australia were attended, to engage in the research in the field.

In addition to these, I was the co-proposer and co-convenor of a special session focusing on *Integrating Humanitarianism in Engineering Education* at the 2017 AAEE Annual Conference. This was the first time this had been a focus area for an AAEE conference. In total, eight papers were presented as part of the special session. Further academic impacts have been achieved through personal awards received over the duration of the research. These are all peer-reviewed, from institutional to national level (see Section 1.5 for details).

10.2.3 Developments in Australia

The growth of HumEngEdu until 2017 was captured in Chapter 9. This is summarised again here in relation to this research, as well as expanded for developments since 2017 (to the submission of this work in 2019). At the start of 2015, when this study commenced, there were no programs or pathways for HumEngEdu available in Australia or NZ, no academic positions in the area, and the first international EWB Humanitarian Design Summit (EWB Summit) to Cambodia had just been piloted in January. During 2015, a number of firsts for Australian education were completed as part of this study:

- The first regular dedicated Humanitarian Engineering course was offered at an Australasian university (EfaHC).
- The first time the EWB Summit was offered within a dedicated course for full unit credit value (via the EfaHC course).
- The pathway developed here was finalised as the first HumEng pathway across all four years of an engineering degree in Australia.
- The first student to complete all the elements of the pathway graduated at the end of 2015. This marked the first "humanitarian engineering graduate" in Australasia, being the first engineer to undertake a cohesive pathway of HumEngEdu experiences from their first year.

The following year (2016), the first formal award program in Australasia was established, a graduate diploma at the University of Canterbury in Christchurch, NZ. The same year the first humanitarian engineering named academic position was created at The University of Sydney, Australia. In 2017, the University of Sydney launched a four course major in Humanitarian Engineering. By 2019, formal programs are in place at two more universities in Australia and EWB Summits are offered regularly during the Australia winter and summer to countries including Cambodia, India, Nepal, Malaysia, and the Pacific.

This research captures this growth, and was central to it. The curriculum design and content used in EfaHC was adopted by at least six other universities in Australia. This supported universities to offer a dedicated course which the EWB Summit, or other similar experiences, could be incorporated into. This is across the breadth of Australian universities including Go8 (Group of Eight research-intensive) and ATN (Australian Technology Network) members. That the same international experience, in this case the EWB Summit, was the catalyst for developing a course has made potentially made dissemination more straight-forward. However, as is the case at the ANU, different experiences from multiple providers are now being incorporated into the same course.

The research in Chapter 2 highlighted the need for national discussions and potential agreement for core competencies and terminology for HumEng. Based on the rapid growth of course and program offerings, I helped to co-establish (and un-officially convene) what has now, as of 2019, become the *Humanitarian Engineering Network of Australasia* (HENA). This is an informal network of the universities delivering HumEngEdu courses as well as external organisations including EWB and Unbound. The special session at the AAEE 2017 conference and HENA prompted a national response for the continued growth of HumEng. This is captured in the ACED position statement in Appendix VIII, to set a goal for national collaboration to help shape HumEng within the broader engineering profession. How this could happen is in current discussion (see Section 1.5 for the most recent developments).

10.3 Research Challenges and Limitations

While this research has made positive contributions and impacts for engineering education at the ANU and contributed to national growth and dialogue, it is not without challenges or limitations. The mixed-methods study design used proved to be beneficial and flexible, allowing a range of data to be collected and analysed. Data was able to be integrated and validated across multiple sources as planned, leading to greater confidence in the overall findings.

One challenge was repeat surveys where a student could complete two very similar surveys at the same time. For example, a student starting a HumEng research project on the back of completing an international experience would have two surveys to complete. While this did not affect the results, it could have been more efficient. Including an anonymous key on survey responses could have saved time for students. In addition, this could have allowed responses over the duration of the research to be linked for changes across years or between experiences.

Identifying specific cohorts for comparison was challenging. Data was collected directly from students before and after an international HumEng experience. A student cohort with these experiences could also be identified from the third/fourth year cohort surveys, but not exactly the same students (see Chapter 7 for details). Hence, such data had to be analysed individually, it could not be combined before analysis.

The breadth and volume of data collected was substantial, and in the end not all was used. Data used focused on primary sources and did not include sources generated for marketing or outreach purposes. Focus groups using a visual pathway similar to the outcomes created by Pasque et al (2009) was tested but not found particularly useful, as it could not capture individual student voices, although it did help to contribute to questions developed for interviews. Similarly, a spectrum-type activity (based on Bielefeldt et al 2013) focusing on humanitarian engineering rather than LTS was used with academics at a conference workshop, but found to produce too much variation to be helpful.

Although beyond the scope of this project, an identifiable gap is that no data was collected from communities or partners in terms of impacts and resources committed and support provided. Impacts were only assessed from a student perspective. As mentioned in Chapter 1, taking a partnership approach to engagement and service-learning, and the fact that there have been multiple projects and engagements with partners over a number of years, it is assumed student engagement is seen by those partners as providing a benefit, although this should be tested in future work (see Section 1.4).

There was a lack of direct industry engagement in the development of the pathway. Community partners were involved for specific projects and topics, and informal discussions on the preparation and background expertise of students. This did help to shape the pathway. The fact that long term programs with multiple projects over a number of years were established with numerous external partners is taken as some validation of the approach and benefits they were receiving. Again, this should be explored in future work (see below).

No data was collected from employers on the suitability or otherwise of graduates for engineering roles. This was only drawn from graduate perceptions of their employability and experiences during recruitment processes. While an enhanced perception of employability for a graduate is real and positive, direct data from employers would have been beneficial to understand their perspectives with regard to employment and job function. The outcomes for employability only emerged from the data, and time and resources were not available to then collect data from employers or recruiters.

As highlighted in Chapter 1, the researcher was intimately involved with the design and delivery of all the new aspects of the HumEng pathway. When combined with education roles and delivery in existing core engineering courses and project supervision, the researcher was involved in almost all aspects of some students' HumEng experiences. Potential issues from this were addressed through the involvement of multiple co-authors and seeking peer-review during the publication process. This provided a greater level of peer involvement and critique of the work than a traditional thesis. However, this did lead to challenges with the final compilation. Publications generally follow the order of work undertaken. However, the publication in Chapter 2 has gone through a much longer review process than all the other articles and at time of submission had not been accepted for publication.

10.4 Current and Further Work

There are two main areas of work building from this study: continued research at the ANU; and national efforts on HumEng.

10.4.1 Research at the ANU

At the ANU, the same data gathered in this study for the last 2 ½ years will continue to be collected. This includes data from individual HumEng experiences as well as a further baseline from the overall 3rd/4th year cohort. These will contribute to a larger data pool to make more comparisons and quantitative analysis. Modifications to individual data collection instruments may be made based on the findings here. Where possible, data collection may take place with respect to the outcomes from this study, particularly the Minor in Humanitarian Engineering (described in Chapter 7), and potential changes to the core of the degree program (outlined in Chapter 8).

Interviews with graduates upon completion will continue. This will include students with two or more HumEngEdu engagements, as well as with a range of graduates who do not meet this criteria, to allow for greater comparison than can be achieved through the existing student profile surveys. In addition, follow-up interviews with graduates interviewed for this research further into their professional careers will commence. This will be 3-5 years post degree completion to provide an opportunity to assess HumEng knowledge, professional practice, and career changes and aspirations. The first graduate interviews in this work commenced at the end of 2016, meaning participants will be three years post completion in 2019, the year this thesis was submitted. Data and evidence from employers would be a further perspective to consider to evaluate impacts for employability.

New research, particularly interviews, would aim to further explore key areas identified in the individual Chapters here. This includes the role of identity, study and career motivations, previous community engagement experiences, and relationships to gap years. Some of these, such as identify and motivations, may have a more significant role as suggested in research exploring areas related to broader questions for engineering education and practice including socially engaged engineers (Litchfield and Javernick-Will 2015;2016), social justice (Cech 2013) and engineering mindsets (Riley 2008). Further research should include the external impact of education programs and initiatives including short-term international experiences (such as EWB Summits) and final year projects (as discussed further in 10.4.2 below).

10.4.2 Sector Research and Engagement

As the first large scale study of students engaging with HumEngEdu in Australia, there are lessons learnt for research at established and emerging programs. The aim is to collect comparable data from multiple institutions in Australasia to build a more complete picture of student engagement with HumEngEdu. Upon submission of this work, this has commenced with data being collected at three other institutions and discussions with a number of others. This will help to investigate broader impacts resulting from HumEngEdu, such as integration of study-abroad experiences, identity, motivations, and gender inclusion.

In exploring HumEngEdu at other Australian universities, the impact of local institutional contextual factors such as funding, structures, missions, and academic interests can be explored. This may identify institutional factors that contribute to approaches adopted and outcomes sought, to again provide further lessons for other institutions establishing initiatives in the area. A comparison to explore here is the different understandings of HumEng internationally and the relationship to the histories of individual countries as identified in Chapter 2. This could adopt a postcolonial lens (as covered in work such as Tikly 2001, Pashby and de Oliveira Andreotti 2016) and explore potential links between historical development interventions and if these are reinforced in HumEngEdu. This is particularly relevant given the globalisation of both higher education and engineering. In Australia, this could explore both Australia's international development work particularly in the Pacific as well as domestic dialogue including the decolonising of universities and curriculum (as discussed in Mackinlay and Barney 2014, Harvey and Russell-Mundine 2019, McLaughlin and Whatman 2007).

At a national level, research will be undertaken by universities to help shape dialogue on the potential recognition of HumEng within the engineering profession. This can extend the research and benchmarking in Chapter 2 as well as findings and outcomes in Chapters 5-8. Alternative models for HumEngEdu identified in Chapter 2 such as integrated versus stand alone can be evaluated from a national perspective and the potential for benchmarking and standards to be articulated. Key international networks and organisations involved with the broad area of HumEng (and its other terms) can be brought into discussions. Such dialogue provides opportunities for data collection and analysis from proposals, documents, workshops, and stakeholders. This gives the opportunity to record, evaluate and critique these national discussions, with lessons learnt for other emerging areas of engineering practice, or other countries with significant HumEng programs.

An additional area of research is engineering practice, in particular the engagement and interactions between engineers and non-engineers involved with technology design, development, and use. New research will investigate how this interaction takes place, who contributions what and when to discussions, how decisions are made, and how community goals and aspirations can be articulated and met. This will use a number of projects as case studies to capture and evaluate the interactions that occur. Some of these are case studies from HumEng projects which have emerged from this research, while others will focus on community-led projects in Australia. This requires more evaluation from a community and external partner perspective, highlighted as a limitation in this work. Again, this research seeks to influence engineering practice, but would not be limited to humanitarian action and development contexts, rather any context where community aspirations and goals can be supported by engineering work and technology development.

10.5 Final Reflections

This study has achieved many of the personal and professional aims it was intended to. It provided an opportunity to explore an area of deep personal interest, and investigate the excitement from students from engaging in HumEng initiatives. The opportunity to focus on just HumEng education at one institution for 3 ½ years has led to numerous impacts. First, to the students. To create educational experiences which contribute to greater motivations, satisfaction and enjoyment from students has been deeply rewarding, and is unlikely to have happened without the time and resources to commit to this study. Similarly, I feel fortunate to have worked with a range of students and external groups on projects with a clear and present need. Students and partners have been more than generous with their time and commitments, sharing their stories, aspirations and frustrations. This work simply would not have happened if that was not the case.

The approach to complete the thesis by publication has been rewarding. While this introduced additional time for peer-review and copyediting (which has been most challenging for Chapter 2), it has provided a much greater level of peer input into the work. I think it has also been a more enjoyable and social approach, allowing me to work with a number of existing and new colleagues and peers. It may however have created overlap between individual articles for the reader.

I feel this work has made positive contributions to the education of engineering students, and through them, to their work with a range of organisations, stakeholders, the engineering professional, and society at large. However, while influencing change at one institution is a step, it is only by changes at a national level in both education and engineering practice that long-term, sustainable and lasting change will occur. This is the change that is required to ensure the engineering profession is contributing to positive social impact and improving human well-being. HumEng can contribute to this, by emphasising quality of life as the central tenet of engineering, by creating a more inclusive and diverse engineering profession, and actively engaging all members of society into the process of engineering in order to achieve goals and aspirations.

Over the course of this research, I was fortunate to receive the following awards:

- 2017: Australian Award for University Teaching Award for Teaching Excellence in the Physical Sciences and Related Studies (including Architecture, Building and Planning, Engineering, Computing and Information Science) discipline category.
- 2016: Office for Learning and Teaching (OLT) National Citation for Contributions that Enhance Student Learning for *leadership in the field of engineering through the development of a sector leading enriching student humanitarian engineering pathway at ANU.*
- 2015: ANU Vice-Chancellors Award for Programs that Enhance Student Learning.

On a personal level this is satisfying. These awards provide a level of additional confidence to continue this work, and some level of indication that the work is relevant and of high-quality, as well validating a number of career decisions.

Challenges were present throughout this work on names, understandings and definitions. Different definitions in different countries, new interpretations of long-established terms (such as Humanitarian in HumEng in Australasia), and varying philosophical perspectives on engineering have been ever present. These differences have clearly not stopped development of education and work, but I believe they need to be addressed and considered if the area is to further expand. This needs to be first through national dialogue engaging educators, practitioners and professional associations. This is required to build community and external trust in the area, and apply the same level of rigour, review and oversight as other aspects of engineering practice. I contributed to a proposal for a *Community of Practice for Humanitarian Engineering* in Engineers Australia which follows the development of the ACED position statement. This was submitted to EA for consideration two weeks before the completion of this thesis. I hope this will provide the platform for broader dialogue and discussion of the area in Australia at least, but represents a potential significant step for the field.

In parallel to these actions, the bringing together of engineering and technology with humanitarian and development work is expanding rapidly. In 2019 alone, I will have or will be attending the following conferences seeking to make the links from both the engineering and development sides:

- 2019 Australia Aid Conference at the ANU, which included a session on “Technology and Aid” and blockchain.
- 2019 Australian Systems Engineering / Test and Evaluation (SETE) Annual Conference, which includes a panel session on “Tackling the UN’s Sustainable Development Goals and the Role of Systems Engineering”.
- 2019 World Engineers Convention in Melbourne which is organised by six themes covering the SDGs.

It is my hope that HumEng can realise the potential of these connections and forge strong ongoing links for the future and the challenges and opportunities it will bring.

References[1]

ABC (2017) *Do most Canberrans really work in the public service?* http://www.abc.net.au/news/specials/curious-canberra/2017-11-20/are-all-canberrans-public-servants/9151638, last accessed 3/2/2018.

ABS (2017) *Ten years of growth: Australia's population hot spots,* http://www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/3218.0Media%20Release12016?opendocument&tabname=Summary&prodno=3218.0&issue=2016&num=&view=, last accessed 3/2/2018, Australian Bureau of Statistics.

ACED (2016) *Promoting engagement between industry and universities for improving engineering graduate capabilities and accelerating innovation*, Position Statement December 2016, Australian Council of Engineering Deans.

ACED (2017) *Increasing the Participation of Women in Engineering Education*, Position Statement March 2017, Australian Council of Engineering Deans.

ACED (2019) *Position Statements*, Australian Council of Engineering Deans, http://www.aced.edu.au/index.php/blog-3/position-statements, last accessed 30/03/2019

ACFID (2015) *About ACFID*, https://acfid.asn.au/about, last accessed 21/4/2018

ACOSS (2014) *Poverty in Australia*, Australian Council of Social Service, NSW, Australia.

ANU (2017a) *ANU Staff Data Summary Report*, Australian National University.

ANU (2017b) *ANU Student Data Summary Report*, Australian National University.

Berg, D. R., Lee, T., and Buchana, E. A. (2016) A Methodology for Exploring, Documenting, and Improving Humanitarian Service Learning in the University, *Journal of Humanitarian Engineering* 4(1).

Bielefeldt, A. R., and Canney, N. (2014) Impacts of Service-Learning on the Professional Social Responsibility Attitudes of Engineering Students, *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, 9(2), 47–63.

Bielefeldt, A. R., Canney, N., Swan, C., and Knight, D. W. (2016) Contributions of Learning through Service to the Ethics Education of Engineering Students, *International Journal for Service Learning in Engineering*, 11(2).

[1] This contains references used in Chapters 1 and 10 and any chapter foreword only. Individual chapters, which are standalone publications, have their own self-contained references for the published article.

Bielefeldt, A., Paterson, K., and Swan, C. (2009) *AC 2009-1972: Measuring the Impacts of Project-Based Service Learning*, American Society for Engineering Education.

Bielefeldt, A., Paterson, K., Swan, C., Pierrakos, O., Kazmer, D. O., and Soisson, A. (2013) Spectra of Learning Through Service Programs, *120th ASEE Annual Conference and Exposition,* Atlanta, June 2013.

Bourn, D., and Neal, I. (2008) *The Global Engineer: Incorporating global skills within UK higher education of engineers*, Engineers Against Poverty, London.

Bratton, M. (2014) Global TIES: Ten Years of Engineering for Humanity, *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, Vol 9 (Fall), 205–221.

Brown, N., Baynard-Smith, P., Smith, J., Thomson, A., and Browne, C. (2018) An NGO-university partnership for sustainable engineering research solutions, *Development Bulletin*, Issue 79, January 2018.

Burnham, M. G. (2009) The 'systems approach' to human problems: How humanitarian engineering can help, *ISTAS'09. IEEE International Symposium on Technology and Society*, 1–10), IEEE 2009.

Canney, N., and Bielefeldt, A. (2015) A framework for the development of social responsibility in engineers, *International Journal of Engineering Education*, 31(1), 414–424.

Case, J. M., and Light, G. (2011) Emerging methodologies in engineering education research, *Journal of Engineering Education*, 100(1), 186.

Cassells R., Duncan A., Abello A., D'Souza G., and Nepal B. (2012) *Smart Australians: Education and Innovation in Australia, AMP.NATSEM Income and Wealth Report*, Issue 32, October 2012, Melbourne, AMP.

Cech, E. (2013) *Chapter 4: The (Mis)Framing of Social Justice: Why Ideologies of Depoliticization and Meritocracy Hinder Engineers' Ability to Think About Social Injustices*. In J. Lucena (ed.), *Engineering Education for Social Justice: Critical Explorations 67 and Opportunities, Philosophy of Engineering and Technology 10*, Springer Science+Business Media Dordrecht 2013.

CECS (2018) *People*, https://eng.anu.edu.au/people, last accessed, 3/2/2018.

CoA (2017) *Closing the Gap Prime Minister's Report 2017*, Department of the Prime Minister and Cabinet, Commonwealth of Australia.

Conlon, E. (2008) The new engineer: between employability and social responsibility. *European Journal of Engineering Education*, 33(2), 151–159.

Charmaz, K. (1996) The search for Meanings–Grounded Theory. In Smith, J. A., Harre, R., and Van Langenhove, L. (Eds.), *Rethinking Methods in Psychology*, 27-49.

CRED (2018) *Natural Disasters 2017*. Brussels: CRED (Centre for Research on the Epidemiology of Disasters), EM-DAT file dated 02/07/2018.

Creswell, J. (2003) *Research design: Qualitative, quantitative, and mixed-method approaches*, 2nd edition, Sage Publications, California.

Crotty, M. (1998) *The foundations of social research: Meaning and perspective in the research process*, Thousand Oaks, CA, Sage.

Cummings, M. A. T., Huff, J., Oakes, W. C., and Zoltowski, C. B. (2013) An assessment approach to project-based service learning, *120th ASEE Annual Conference and Exposition,* Atlanta, June 2013.

Cuny, F. (1983) *Disasters and Development*, Oxford University Press, NY.

Cutler, S., Borrego, M., and Loden, D. (2011) An evaluation of the Australian engineers without borders challenge from the course coordinators' perspectives, *2011 Frontiers in Education Conference (FIE)*, Rapid City, SD, 2011, pp. T1G-1-T1G-6.

Department of Education and Training (n.d.) *uCube*, http://highereducationstatistics.education.gov.au/, last accessed 21/4/2018.

Dowling, D., and Hadgraft, R. (2012) What should we teach? Defining your discipline to drive curriculum renewal: an environmental engineering case study. Presented at the *SEFI 40th annual conference*, 23-26 September 2012, Thessaloniki, Greece.

EA (2011) *Stage 1 competency standards for professional engineer*, Engineers Australia, Canberra.

EA (2013) *Our Code of Ethics*, Engineers Australia, Canberra.

EA (2017a) *Our Strategic Direction 2017/18 - 2019/20*, Engineers Australia, Canberra

EA (2017b) *Australian Council of Engineering Deans* https://www.engineersaustralia.org.au/aced, (last accessed 23/06/2017)

EA (2017c) *A profession for all*, Engineers Australia.

EWB (2017) *Our history and culture*, https://www.ewb.org.au/about/ourhistoryandculture, last accessed 3/2/2018.

Greet, N. (2014) *Building a humanitarian engineering network – A collaborative challenge*, Collaborative Outcomes Pty Ltd Australia, 2014

Harvey, A., and Russell-Mundine, G. (2019) Decolonising the curriculum: using graduate qualities to embed Indigenous knowledges at the academic cultural interface, *Teaching in Higher Education*, 24:6, 789-808.

Huff, J., Zoltowski, C. B., Oakes, W. C., and Adams, R. (2013) Making Sense of Design: A Thematic Analysis of Alumni Perspectives, *120th ASEE Annual Conference and Exposition,* Atlanta, June 2013.

IEA (2018) *Energy Poverty,* International Energy Agency, https://www.iea.org/topics/energypoverty/, last accessed 2/3/2018.

iXc (2017) *About Us*, https://ixc.dfat.gov.au/about-us/, last accessed 25/01/2019 InnovationXChange.

Jesiek, B. K., Zhu, Q., Woo, S. E., Thompson, J., and Mazzurco, A. (2014) Global engineering competency in context: Situations and behaviors, *Online Journal for Global Engineering Education*, 8(1), 1.

Johnson, R. B., and Onwuegbuzie, A. J. (2004) Mixed Methods Research: A Research Paradigm Whose Time Has Come, *Educational Research,* 33 (7), October.

Jolly, L., Jolly, H., and Brodie, L. (2013) Epistemological problems in engineering education, *Proceedings of the 2013 AAEE Conference,* Gold Coast, Australia, 2013.

Jolly, L. (2014) *Curriculum renewal in engineering through theory-driven evaluation*, Office for Learning and Teaching, Department of Engineering, Sydney.

Komives, S. R., Longerbeam, S. D., Owen, J. E., Mainella, F. C., and Osteen, L. (2006) A leadership identity development model: Applications from a grounded theory, *Journal of College Student Development*, 47(4), 401–418.

Komives, S. R., Owen, J. E., Longerbeam, S. D., Mainella, F. C., and Osteen, L. (2005) Developing a leadership identity: A grounded theory, *Journal of College Student Development*, 46(6), 593–611.

Lam, J. W., Mah, F. J., Miller, P. B., and Meikleham, A. (2016) Developing Role Models for Engineering and Sustainable Development: Engineers Without Borders' Global Engineering

Certificate, In Leal Filho, W., and Nesbit S. (Eds.), *New Developments in Engineering Education for Sustainable Development*, Cham, Springer International Publishing, 139–149.

Litchfield, K., Javernick-Will, A., and Maul, A. (2016) Technical and Professional Skills of Engineers Involved and Not Involved in Engineering Service: Technical and Professional Skills of Engineers in Engineering Service, *Journal of Engineering Education*, 105(1), 70–92.

Litchfield, K., and Javernick-Will, A. (2014) Investigating Gains from EWB-USA Involvement, *Journal of Professional Issues in Engineering Education and Practice*, 140(1).

Litchfield, K., and Javernick-Will, A. (2015) "I am an Engineer AND": A Mixed Methods Study of Socially Engaged Engineers, *Journal of Engineering Education*, 104(4), 393-416.

Litchfield, K., and Javernick-Will, A. (2016) Socially Engaged Engineers' Career Interests and Experiences: A Miner's Canary, *Journal of Professional Issues in Engineering Education and Practice*, 143(1).

Lohmann, J. R., Rollins, H. A., and Joseph Hoey, J. (2006) Defining, developing and assessing global competence in engineers, *European Journal of Engineering Education*, *31*(1), 119–131.

Mackinlay, E., and Barney, K. (2014) Unknown and Unknowing Possibilities: Transformative Learning, Social Justice, and Decolonising Pedagogy in Indigenous Australian Studies, *Journal of Transformative Education*, 12(1), 54-73.

McLaughlin, J. M., and Whatman, S. L. (2007) Embedding Indigenous perspectives in university teaching and learning: lessons learnt and possibilities of reforming / decolonising curriculum. In *Proceedings 4th International Conference on Indigenous Education: Asia/ Pacific*, Vancouver, Canada.

Mitcham, C. (2009) A historico-ethical perspective on engineering education: from use and convenience to policy engagement, *Engineering Studies*, 1(1), 35-53.

NAE (2008) *NAE Grand Challenges for Engineering*, National Academy of Engineering.

NDIS (n.d.) *Federal Funding*, NDIS About Us, https://www.ndis.gov.au/about-us/governance/federal-funding, last accessed 21/4/2018.

Nugent A., Lodge, J. M., Carroll, A., Bagraith, R., MacMahon, S., Matthews, K. E. and Sah, P. (2019) *Higher Education Learning Framework: An evidence informed model for university learning*, The University of Queensland, Brisbane.

OECD (2017). *Humanitarian Development Coherence*, Development Co-operation Directorate, OECD, Paris, France.

Ortega y Gasset, José (1961) *History as a system, and other essays toward a philosophy of history. With an afterword by John William Miller*, Norton, New York.

O'Shea, J., and Baillie, C. (2011) Engineering education towards social and environmental justice, *Australasian Association for Engineering Education Conference 2011: Developing engineers for social justice: Community involvement, ethics & sustainability*, Fremantle, Western Australia, December 2011.

Pashby, K., and de Oliveira Andreotti, V. (2016) Ethical internationalisation in higher education: interfaces with international development and sustainability, *Environmental Education Research*, 22:6, 771-787.

Pasque, P. A., Bowman, N. A., Small, J. L., and Lewis, R. (2009) Student-Created Curricular and Co-Curricular Pathways Toward Participation in a Diverse Democracy, *Multicultural Perspectives*, 11(2), 80–89.

Paye, S. (2010) Ingénieurs Sans Frontières in France: From Humanitarian Ideals to Engineering Ethics, *IEEE Technology and Society Magazine*, 29(1), 20–26.

Pierrakos, O., Nagel, R., Pappas, E., Nagel, J., Moran, T., Barrella, E., and Panizo, M. (2013) A mixed-methods study of cognitive and affective learning during a sophomore design problem-based service learning experience. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, Fall 2013, 1–28.

Plett, M., Jones, D., Crawford, J., Floyd Smith, T., Peter, D., Scott, E., Wilson, D., Bates, R., and Veilleux, N. (2011) *AC2011-720: STEM Seniors: Strong connections to Community are Associated with Identify and Positive Affect in the Classroom*, American Society for Engineering Education.

RAE (2015) *Engineering at the heart of society*, https://www.youtube.com/watch?v=fFW1wWgsSNY, last viewed 21/4/2018

RedR (2017) *Our History*, https://www.redr.org.au/about-us/our-history/, last accessed 3/2/2018.

Riley, D. (2008) *Engineering and Social Justice*, Morgan & Claypool Publishers.

Schneider, J., Leydens, J. A., and Lucena, J. (2008) Where is 'Community'?: Engineering education and sustainable community development, *European Journal of Engineering Education*, 33(3), 307–319.

Smith, J., Brown, L., and Cahill, A. (2009) Engineering social change: Engaging undergraduate engineers in community development research, 20th *Annual Conference for the Australasian Association for Engineering Education*, Adelaide, 6 - 9 December 2009.

Smith, J., Turner, J., and Brown, N. (2015) *Collaborative development of a blended humanitarian engineering course for the Australian engineering sector*, Final Report, Office for Learning and Teaching, Department of Education, Sydney, Australia.

Sphere (n.d.) *The Sphere Project,* http://www.sphereproject.org/about/, last accessed 8/5/2018.

Strauss, A., and Corbin, J. (1994) Grounded theory methodology, *Handbook of qualitative research*, 17, 273-85.

Tayler, Y. (2016) Humanitarian Engineering: Innovative Approaches and Partnerships in Crisis Response, *MENA Knowledge and Learning Quick Notes Series*, 157, June.

Tikly, L. (2001) Globalisation and Education in the Postcolonial World: Towards a conceptual framework, *Comparative Education*, 37:2, 151-171.

UA (2017) *Data Snapshot*, Universities Australia, Deakin.

UN (2016) *Final list of proposed Sustainable Development Goal indicators*, United Nations.

UNESCO (2010) *Engineering: Issues Challenges and Opportunities for Development*, United Nations Educational, Scientific and Cultural Organization.

UNHCR (2018) *Cluster Approach (IASC)*, UNHCR Emergency Handbook Version 1.8, 20/4/2018.

Vandersteen, J. D. J., Baillie, C., and Hall, K. (2009) International humanitarian engineering. *IEEE Technology and Society Magazine*, 28(4), 32–41.

Walther, J., Kellam, N., Sochacka, N., and Radcliffe, D. (2011) Engineering competence? An interpretive investigation of engineering students' professional formation, *Journal of Engineering Education*, 100(4), 703.

WHO (2017a) *Sanitation*, World Health Organisation, http://www.who.int/mediacentre/factsheets/fs392/en/, last accessed 3/2/2018.

WHO (2017b) *Drinking Water*, World Health Organisation, http://www.who.int/mediacentre/factsheets/fs391/en/, last accessed 3/2/2018.

Appendix I: Human Ethics Protocols

Introduction

This Appendix provides the participant information sheets and consent forms for the two human ethics protocols the research was completed under. Both protocols were approved by the ANU Human Ethics Committee. Each protocol was updated with variations as the research developed, and major amendments are included here.

Participant Information Sheet 2015/389: Original

Researcher:

The primary researcher for this project is Jeremy Smith, a postgraduate student in the Research School of Engineering (RSEng) at the College of Engineering and Computer Science (CECS) at the Australian National University (ANU) in Canberra.

Project Title: An Australian Humanitarian Engineering Course

Project Outline:

This research is part of an Office for Learning and Teaching (OLT) funded project titled *Collaborative Development of a Blended Humanitarian Engineering Course for the Australian Engineering Sector* which was awarded to the ANU and Engineers Without Borders Australia (EWB) in 2014. This project is developing a new engineering course called *Engineering for a Humanitarian Context* to be delivered at the ANU in 2015. To assist with an evaluation of the course and its content, assignment submissions and entry and exit surveys will be reviewed. This is to gain insights into the content provided to ensure its relevance for the target student cohort. Outcomes from this research will be used to help inform the development of humanitarian engineering education initiatives particularly in Australia. We intend to present the results at engineering education conferences or in a relevant journal article.

Participant Involvement:

Students in the course will be asked to allow their assignments and results from course entry and exit surveys to be used to assess and evaluate aspects of the course, focusing on the content and resources available. Participation is voluntary and students may withdraw their consent at any time without penalty before the publication or presentation of any research results. The use of assignments and survey outcomes in this research will in no way impact on students' examination or marks for the course. If a participant withdraws, their assignments will not be used for any analysis or evaluation and anonymous quotes will not be used. Any outcomes from the research, such as presentations or publications, will be available to participants at the following shared link: https://www.dropbox.com/sh/8y1tzajmfmmtd7b/AACV7b_QeYIEL6fTlWTECMzwa?dl=0

Confidentiality

All assessment items and surveys collected will be de-personalised and kept confidential to ensure participants will be non-identifiable for publications although anonymous quotes may be used. Confidentiality will be protected as far as the law provides.

Data Storage:

Once collected de-identified data will be stored in a password protected network drive at the ANU accessed only by the researchers and kept for five years from publication at which point it will deleted.

Queries and Concerns:

Participants can raise queries on the project by contacting Jeremy Smith at jeremy.smith@anu.edu.au or (02) 6125 0468, or contacting the postgraduate research supervisor for the work Paul Compston at paul.compston@anu.edu.au

Ethics Committee Clearance:

The ethical aspects of this research have been approved by the ANU Human Research Ethics Committee. If you have any concerns or complaints about how this research has been conducted, please contact:

Ethics Manager
The ANU Human Research Ethics Committee
The Australian National University
Telephone: +61 2 6125 3427
Email: Human.Ethics.Officer@anu.edu.au

Consent Form 2015/389: Original

WRITTEN CONSENT for Participants

An Australian Humanitarian Engineering Course

I have read and understood the Information Sheet you have given me about the research project, and I have had any questions and concerns about the project (listed here

____

____)

addressed to my satisfaction. I agree to participate in the project. YES ☐ NO ☐

I agree to my assignments being used in this research YES ☐ NO ☐

I agree to anonymous quotes being made for publication YES ☐ NO ☐

I agree to my entry and exit survey responses being used in this research

YES ☐ NO ☐

Name…..:…………………………………………….

Signature:……………………………………………. Date: ……………………

Participant Information Sheet 2015/389: Amended 2016

Researcher:

The primary researcher for this project is Jeremy Smith, a postgraduate student in the Research School of Engineering (RSEng) at the College of Engineering and Computer Science (CECS) at the Australian National University (ANU) in Canberra.

Project Title: An Australian Humanitarian Engineering Course

Project Outline:

Description and Methodology: This research seeks to evaluate the inclusion of the EWB Humanitarian Design Summits into curriculum at the ANU via the engineering special topic, *Engineering for a Humanitarian Context* or to contribute to the work experience requirement in engineering. To assist with an evaluation of the course, its content and the inclusion of the EWB Summit, assignment submissions and entry and exit surveys will be reviewed. This is to gain insights into the content provided and support structures to ensure its relevance for the target student cohort.

Participants: This research will involve students taking part in the EWB Humanitarian Design Summit to Cambodia in June and July 2016.

Use of Data and Feedback: Outcomes from this research will be used to help inform the development of humanitarian engineering education initiatives at the ANU and nationally. We intend to present the results at engineering education conferences or in a relevant journal article.

Participant Involvement:

Voluntary Participation and Withdrawal: Participation is voluntary and students may withdraw their consent at any time without penalty before the publication or presentation of any research results. The use of assignments and survey outcomes in this research will in no way impact on students' examination or marks for the course. If a participant withdraws, their assignments will not be used for any analysis or evaluation and anonymous quotes will not be used.

Participation in Research: Students in the course will be asked to allow their assignments and results from course entry and exit surveys to be used to assess and evaluate aspects of the course, focusing on the content and resources available.

Location and Duration: Entry and exit surveys will be provided to students during workshops, with time available to complete them. Assignments will be emailed to the course coordinator due to the nature of the course.

Benefits: Results from surveys and assignment tasks will be used to support students and inform curriculum around their involvement in the EWB Humanitarian Design Summits. Any outcomes from the research, such as presentations or publications, will be available to participants at the following shared link:
https://www.dropbox.com/sh/8y1tzajmfmmtd7b/AACV7b_QeYIEL6fTlWTECMzwa?dl=0

Confidentiality:

All assessment items and surveys collected will be de-personalised and kept confidential to ensure participants will be non-identifiable for publications although anonymous quotes may be used. Confidentiality will be protected as far as the law provides.

Privacy Notice:

In collecting your personal information within this research, the ANU must comply with the Privacy Act 1988. The ANU Privacy Policy can be found at https://policies.anu.edu.au/ppl/document/ANUP_010007 and contains information about how you can

- Have access or seek correction to your personal information.
- Complain about a breach of an Australian Privacy Principle (APP) by ANU and how ANU will handle the complaint.

Data Storage:

Where: Once collected de-identified data will be stored in a password protected network drive at the ANU accessed only by the researchers.

How Long: Data will be kept for five years from publication of outcomes.

Handling of Data After Storage Period: After the storage period of five years data will deleted.

Queries and Concerns:

Participants can raise queries on the project by contacting Jeremy Smith at jeremy.smith@anu.edu.au or (02) 6125 0468, or contacting the postgraduate research supervisor for the work Paul Compston at paul.compston@anu.edu.au

Ethics Committee Clearance:

The ethical aspects of this research have been approved by the ANU Human Research Ethics Committee. If you have any concerns or complaints about how this research has been conducted, please contact:

Ethics Manager
The ANU Human Research Ethics Committee
The Australian National University
Telephone: +61 2 6125 3427
Email: Human.Ethics.Officer@anu.edu.au

Consent Form 2015/389: Amended 2016

WRITTEN CONSENT for Participants

An Australian Humanitarian Engineering Course

I have read and understood the Information Sheet you have given me about the research project, and I have had any questions and concerns about the project (listed here

____

____)

addressed to my satisfaction. I agree to participate in the project. YES ☐ NO ☐

I agree to my assignments being used in this research YES ☐ NO ☐

I agree to anonymous quotes being made for publication YES ☐ NO ☐

I agree to my entry and exit survey responses being used in this research

YES ☐ NO ☐

Name…..:…………………………………………….

Signature:……………………………………………. Date: ……………………

Participant Information Sheet 2016/550: Original

Researcher:
The primary researcher for this project is Jeremy Smith, a postgraduate student at the Research School of Engineering (RSEng) in the College of Engineering and Computer Science (CECS) at the Australian National University (ANU) in Canberra.

Project Title: Student Outcomes from a Humanitarian Engineering Pathway

General Outline of the Project:
Description and Methodology: This research seeks to evaluate humanitarian engineering education initiatives at the ANU. To support this data will be collected numerous from sources. This includes assignments and surveys for courses with a humanitarian engineering education element or focus, including international experiences and internships. Current students and graduates who have been involved with humanitarian engineering education initiatives will be interviewed individually or in focus groups. These data collection methods are to gain insights into the content, approaches and outcomes of the initiatives to support current and future education initiatives.

Participants: This research will involve participants who have been involved with activities as undergraduate students related to humanitarian engineering education. The target number of student participants is 300 current students and recent graduates. Participants will be asked to provide assessment items related to humanitarian engineering from their courses, as well as any entry or exit surveys for courses with humanitarian engineering elements. Surveys will be conducted for international experiences such as EWB Summits. Interviews and focus group discussions for students and graduates with substantial humanitarian engineering education experience will be conducted.

Use of Data and Feedback: Outcomes from this research will be used to help inform the development of humanitarian engineering education initiatives at the ANU and nationally. Results will be presented at engineering education conferences or in relevant journals. Data and analysis will contribute to the researchers postgraduate studies and thesis. Participants can request copies of any publications resulting from the research. A summary of the results will be presented to participants through existing regular meetings and ANU student discussion forums. Participants can access the summary of results or any papers developed by accessing this public link -
https://drive.google.com/folderview?id=0B6gbOQk0zOdQOG1vRmNuZnVhUUU&usp=sharing

Participant Involvement:
Voluntary Participation and Withdrawal: Participation in this research is voluntary. The use of assignments, interviews and survey outcomes in this research will in no way impact on students' examination or marks for any courses. For surveys conducted in the research you can withdraw your consent without explanation at any point until the data is submitted to the researcher. If you withdraw your consent any surveys will be destroyed. For students providing assessment items or involved with individual interviews, you may withdraw your consent at any time without penalty before the publication or presentation of any research results. If a participant withdraws their consent, their assignments will not be used for any analysis or evaluation and anonymous quotes will not be used. If a participant withdraws their consent for an interview, responses will be destroyed. If consent is withdrawn for participation in a focus group, to the extent possible your

individual responses will destroyed or not used for any analysis or evaluation. At any point during a survey, interview or focus group, you can refuse to answer any question.

Participation in Research: Students undertaking courses with a humanitarian engineering element or focus will be asked to allow relevant assignments from the course to be used to assess and evaluate aspects of the course and the learning achieved. Any assignments will be de-identified before being evaluated for this research. Students in a course will be asked to allow results from course entry and exit surveys to be used, which will be anonymous. Beyond specific courses, participants will be asked to be involved with an individual interview or focus group with the researcher. These will cover the participants' experiences while studying at ANU to identify key elements of their learning achieved particularly with respect to any humanitarian engineering education. These will be audio recorded and transcribed, and transcripts provided to each participant for review before any analysis is finalised.

Location and Duration: The majority of the research will take place where student learning is occurring, on the ANU campus or overseas where an international experience for course recognition is taking place. If used, assignments will be downloaded from course Wattle sites. Surveys will either be available through course Wattle sites or paper based, in which case time in class will be provided to participants to complete them. Surveys are estimated to take 10-15 min to complete. Individual interviews will ideally be undertaken face-to-face in person, although may be via video conferencing depending on the location of participants. Interviews and focus groups are estimated to take 45-60 mins each. Depending on your level of engagement with humanitarian engineering education, you may be asked to take part in more than one interview or focus group, although this will be over multiple years.

Risks: Depending on your level of engagement with humanitarian engineering initiatives, there is a risk that you may be able to be identified from your responses. This may occur if you have had significant and multiple engagements with humanitarian engineering while studying that have also be made publically available through marketing material or public channels.

Benefits: The potential benefits of this research are to influence the emerging field of humanitarian engineering education in Australia. You may not personally benefit from this research but it will contribute to future humanitarian engineering education at ANU and potentially other universities in Australia. Benefits may also flow to the researcher in terms of publications and postgraduate studies.

Implications of Participation: Participating in this research will not impact on your course marks or grades. Any evaluation of assessment items will be independent of marking and grading.

Confidentiality

Only the nominated researchers will have access to any material you provide. Where collected, assessment items and surveys will be de-personalised and kept confidential to ensure as far as possible participants will be non-identifiable for publications although anonymous quotes or pseudonym attributions may be used. Participants' names, student numbers or contact information will be not be requested or collected for surveys or assignments. Confidentiality will be protected as far as the law allows. Participates from focus group sessions are requested to maintain confidentiality of group discussions and refrain from making statements of a confidential nature or that are defamatory of any person.

Privacy Notice:
In collecting your personal information within this research, the ANU must comply with the Privacy Act 1988. The ANU Privacy Policy is available at https://policies.anu.edu.au/ppl/document/ANUP_010007 and it contains information about how a person can:

- Access or seek correction to their personal information;
- Complain about a breach of an Australian Privacy Principle by ANU, and how ANU will handle the complaint.

Data Storage:
Where: Once collected data will be stored in a password protected network drive at the ANU accessed only by the researchers.

How Long: Data will be kept for five years from collection or from the date of any publication arising from the research.

Handling of Data After Storage Period: After the storage period all data will archived in a de-identified format.

Queries and Concerns:
Participants can raise queries on the project by contacting the researcher Jeremy Smith at jeremy.smith@anu.edu.au or calling on 612 50468. Alternatively you can contact the postgraduate research supervisor for the work Paul Compston at paul.compston@anu.edu.au or 612 58614.

Ethics Committee Clearance:
The ethical aspects of this research have been approved by the ANU Human Research Ethics Committee (Protocol 2016/550). If you have any concerns or complaints about how this research has been conducted, please contact:

Ethics Manager
The ANU Human Research Ethics Committee
The Australian National University
Telephone: +61 2 6125 3427
Email: Human.Ethics.Officer@anu.edu.au

Consent Form 2016/550: Original

WRITTEN CONSENT for Participants

Student Outcomes from a Humanitarian Engineering Pathway

I have read and understood the Information Sheet you have given me about this research project, and I have had any questions and concerns about the project (listed here

____

____)

addressed to my satisfaction.

I agree to participate in the project. YES ☐ NO ☐

I agree to this interview or focus group being audio-recorded YES ☐ NO ☐

I agree to my assignments from ______________________ (enter course code(s))

being used in this research YES ☐ NO ☐

I agree to my survey responses being used in this research YES ☐ NO ☐

I agree to be identified in the following way within research outputs (select one):

Anonymously YES ☐ NO ☐

Pseudonym YES ☐ NO ☐

No attribution YES ☐ NO ☐

Signature:...

Date:..

I would like a copy of any publications resulting from this project YES ☐ NO ☐

If YES, please provide an email contact: ______________________________

Participant Information Sheet 2016/550: Amended 2017

Researcher:
The primary researcher for this project is Jeremy Smith, a postgraduate student at the Research School of Engineering (RSEng) in the College of Engineering and Computer Science (CECS) at the Australian National University (ANU) in Canberra.

Project Title: Student Outcomes from a Humanitarian Engineering Pathway

General Outline of the Project:
Description and Methodology: This research seeks to evaluate humanitarian engineering education initiatives at the ANU. To support this data will be collected from numerous sources. This includes assignments and surveys for courses with a humanitarian engineering education element or focus, including international experiences and internships. Current students and graduates who have been involved with humanitarian engineering education initiatives will be interviewed individually or in focus groups. Understanding of, and background with, humanitarian engineering for staff supporting education initiatives in the area across Australasia will be collected from interviews, focus group workshops, or surveys. These data collection methods are to gain insights into the content, approaches and outcomes of the initiatives to support current and future education initiatives.

Participants: This research will primarily involve participants who have been involved with activities as under- or post-graduate students related to humanitarian engineering education. The target number of student participants is 300 current students and recent graduates. Participants will be asked to provide assessment items related to humanitarian engineering from their courses, as well as any entry or exit surveys for courses with humanitarian engineering elements. Surveys will be conducted for international experiences such as EWB Summits. Interviews and focus group discussions for students and graduates with substantial humanitarian engineering education experience will be conducted. A secondary set of participants are university staff involved with the design, delivery and support of humanitarian engineering education across Australia and New Zealand. For this group, the target number of participants is 20, representing those most involved with the area.

Use of Data and Feedback: Outcomes from this research will be used to help inform the development of humanitarian engineering education initiatives at the ANU and nationally. Results will be presented at engineering education conferences and relevant journals. Data and analysis will contribute to the researchers postgraduate studies and thesis. A summary of the results will be presented to participants through existing regular meetings and ANU student discussion forums. Participants can access the summary of results or any papers resulting from the research by accessing this public link - https://drive.google.com/folderview?id=0B6gbOQk0zOdQOG1vRmNuZnVhUUU&usp=sharing

Participant Involvement:
Voluntary Participation and Withdrawal: Participation in this research is voluntary. The use of assignments, interviews and survey outcomes in this research will in no way impact on students' examination or marks for any courses. For surveys conducted in the research you can withdraw your consent without explanation at any point until the data is submitted to the researcher. If you withdraw your consent any surveys will be destroyed. For students providing assessment items you may withdraw your consent at any time without explanation at any point until the assignment is submitted to the researcher. If a participant withdraws their consent, their assignments will not

be used for any analysis or evaluation and de-identified quotes will not be used. For participants involved with individual interviews, you may withdraw your consent at any time without penalty before the publication or presentation of any research results. If a participant withdraws their consent for an interview, responses will be destroyed. If consent is withdrawn for participation in a focus group, to the extent possible your individual responses will destroyed or not used for any analysis or evaluation. At any point during a survey, interview or focus group, you can refuse to answer any question.

Participation in Research: Students undertaking courses with a humanitarian engineering element or focus will be asked to submit relevant assignments from the course to be used to assess and evaluate aspects of the course and the learning achieved. Students will be asked to de-identify their assignments and submit to the researcher via email or in person. Students in a course will be asked to voluntarily allow results from anonymous course entry and exit surveys to be used. Beyond specific courses, participants will be asked to be involved with an individual interview or focus group with the researcher. These will cover the participants' experiences while studying at ANU to identify key elements of their learning achieved particularly with respect to any humanitarian engineering education. University staff may participate through individual interviews, focus group workshops or anonymous surveys. These will focus on background and delivery of humanitarian engineering education. If consent is provided by a participant, interviews will be audio recorded and transcribed, and transcripts provided to each participant for review before any analysis is finalised.

Location and Duration: The majority of the research will take place where student learning is occurring, on the ANU campus or overseas where an international experience for course recognition is taking place. If permitting their use, participants will de-identify assignments and submit to the researcher via email or in person. Anonymous surveys will either be available through course Wattle sites or paper based, in which case time in class will be provided to participants to complete them. Surveys are estimated to take 10-15 min to complete. Individual interviews will ideally be undertaken face-to-face, although may be via video conferencing depending on the location of participants. Interviews and focus groups are estimated to take 45-60 mins each. Depending on your level of engagement with humanitarian engineering education, you may be asked to take part in more than one interview or focus group, although this will be over multiple years. Engagement with university staff will typically take place during discussions or workshops at conferences or on university campuses, while individual interviews will be via video conferencing or face-to-face depending on availability.

Risks: Depending on your level of engagement with humanitarian engineering initiatives, there is a risk that you may be able to be identified from your responses. This may occur if you have had significant and multiple engagements with humanitarian engineering that have also be made publically available through marketing material or public channels.

Benefits: The potential benefits of this research are to influence the emerging field of humanitarian engineering education in Australia. You may not personally benefit from this research but it will contribute to future humanitarian engineering education at ANU and other universities in Australia. Benefits may also flow to the researcher in terms of publications and postgraduate studies.

Implications of Participation: For students, participating in this research will not impact on your course marks or grades. Any evaluation of assessment items will be independent of marking and grading.

Confidentiality
Only the nominated researchers will have access to any material you provide. Where collected, de-identified assessment items and surveys will be kept confidential to ensure as far as possible participants will be non-identifiable for publications although de-identified quotes or pseudonym attributions may be used. Participants' names, student numbers or contact information will be not be requested or collected for surveys or assignments. Confidentiality will be protected as far as the law allows. Participates from focus group sessions are requested to maintain confidentiality of group discussions and refrain from making statements of a confidential nature or that are defamatory of any person.

Privacy Notice:
In collecting your personal information within this research, the ANU must comply with the Privacy Act 1988. The ANU Privacy Policy is available at https://policies.anu.edu.au/ppl/document/ANUP_010007 and it contains information about how a person can:

- Access or seek correction to their personal information;
- Complain about a breach of an Australian Privacy Principle by ANU, and how ANU will handle the complaint.

Data Storage:
Where: Once collected data will be stored in a password protected network drive at the ANU accessed only by the researchers.

How Long: Data will be kept for five years from collection or from the date of any publication arising from the research.

Handling of Data After Storage Period: After the storage period all data will archived in a de-identified format.

Queries and Concerns:
Participants can raise queries on the project by contacting the researcher Jeremy Smith at jeremy.smith@anu.edu.au or calling on 612 50468. Alternatively you can contact the postgraduate research supervisor for the work Paul Compston at paul.compston@anu.edu.au or 612 58614.

Ethics Committee Clearance:
The ethical aspects of this research have been approved by the ANU Human Research Ethics Committee (Protocol 2016/550). If you have any concerns or complaints about how this research has been conducted, please contact:

Ethics Manager
The ANU Human Research Ethics Committee
The Australian National University
Telephone: +61 2 6125 3427
Email: Human.Ethics.Officer@anu.edu.au

Consent Form 2016/550: Amended 2017

WRITTEN CONSENT for Participants

Student Outcomes from a Humanitarian Engineering Pathway

I have read and understood the Information Sheet you have given me about this research project, and I have had any questions and concerns about the project (listed here

____

____)

addressed to my satisfaction.

I agree to participate in the project. YES ☐ NO ☐

I agree to this interview or focus group being audio-recorded YES ☐ NO ☐ N/A ☐

I agree to my assignments from ________________________ (enter course code(s))

being used in this research YES ☐ NO ☐ N/A ☐

I agree to my survey responses being used in this research YES ☐ NO ☐ N/A ☐

I agree to be identified in the following way within research outputs (select one):

Anonymously YES ☐ NO ☐

Pseudonym YES ☐ NO ☐

No attribution YES ☐ NO ☐

Name:…………………………..…………………….

Signature:…………………………………………….

Date:…………………………………………….……

Participant Information Sheet 2016/550: Amended 2018

Researcher:
The primary researcher for this project is Jeremy Smith, a postgraduate student at the Research School of Engineering (RSEng) in the College of Engineering and Computer Science (CECS) at the Australian National University (ANU) in Canberra. The research also involves Engineers Without Borders Australia (EWB) and the University of New South Wales (UNSW).

Project Title: Student Outcomes from a Humanitarian Engineering Pathway

General Outline of the Project:
Description and Methodology: This research seeks to evaluate humanitarian engineering education in Australia. Data will be collected from numerous sources including assignments and surveys for courses with a humanitarian engineering education element or focus, international experiences and internships. Students and graduates who have been involved with humanitarian engineering education will be interviewed individually or in focus groups. Understanding of, and background with, humanitarian engineering for staff supporting education initiatives in the area across Australasia will be collected from interviews, focus group workshops, or surveys. These data collection methods are to gain insights into the content, approaches and outcomes of the initiatives to support current and future education initiatives.

Participants: This research will primarily involve participants who have been involved with activities as under- or post-graduate students related to humanitarian engineering education. The target number of student participants is 300 students and recent graduates from ANU and 100 students from UNSW. Participants will be asked to potentially provide assessment items related to humanitarian engineering from their courses, or surveys for courses with humanitarian engineering elements. Surveys will be conducted for international experiences such as EWB Summits or when undertaking a humanitarian engineering research or development project. Interviews and focus group discussions for students and graduates with substantial humanitarian engineering education experience will be conducted. A secondary set of participants are university staff involved with the design, delivery and support of humanitarian engineering education across Australia and New Zealand. For this group, the target number of participants is 20, representing those most involved with the area.

Use of Data and Feedback: Outcomes from this research will be used to help inform the development of humanitarian engineering education at the ANU, the UNSW and nationally. Results will be presented at engineering education conferences and in relevant journals. Data and analysis will contribute to the researchers postgraduate studies and thesis. A summary of the results will be presented to participants through meetings and the ANU and the UNSW student discussion forums. Participants can access the summary of results or any papers resulting from the research by accessing this public link - https://drive.google.com/folderview?id=0B6gbOQk0zOdQOG1vRmNuZnVhUUU&usp=sharing

Participant Involvement:
Voluntary Participation and Withdrawal: Participation in this research is voluntary. The use of assignments, interviews and survey outcomes in this research will in no way impact on students' examination or marks for any courses. For surveys conducted in the research you can withdraw your consent without explanation at any point until the data is submitted to the researcher. If you withdraw your consent any surveys will be destroyed. For students providing assessment items you may withdraw your consent at any time without explanation at any point until the assignment

is submitted to the researcher. If a participant withdraws their consent, their assignments will not be used for any analysis or evaluation and de-identified quotes will not be used. For participants involved with individual interviews, you may withdraw your consent at any time without penalty before the publication or presentation of any research results. If a participant withdraws their consent for an interview, responses will be destroyed. If consent is withdrawn for participation in a focus group, to the extent possible your individual responses will destroyed or not used for any analysis or evaluation. At any point during a survey, interview or focus group, you can refuse to answer any question.

Participation in Research: Students undertaking courses with a humanitarian engineering element or focus may be asked to submit relevant assignments from the course to be used to assess and evaluate aspects of the course and the learning achieved. Students will be asked to de-identify their assignments and submit to the researcher via email or in person. Students in a course will be asked to voluntarily allow results from anonymous course entry and exit surveys to be used. Beyond specific courses, participants will be asked to be involved with an individual interview or focus group with the researcher. These will cover the participants' experiences while studying to identify key elements of their learning achieved particularly with respect to any humanitarian engineering education. University staff may participate through individual interviews, focus group workshops or anonymous surveys. These will focus on background and delivery of humanitarian engineering education. If consent is provided by a participant, interviews will be audio recorded and transcribed, and transcripts provided to each participant for review before any analysis is finalised.

Location and Duration: The majority of the research will take place where student learning occurs, on the ANU or the UNSW campus or overseas where an international experience for course recognition is taking place. If permitting their use, participants will de-identify assignments and submit to the researcher via email or in person. Anonymous surveys will either be available through course Learning Management Sites or paper based and are estimated to take 10-15 min to complete. Individual interviews will ideally be undertaken face-to-face, although may be via video conferencing depending on the location of participants. Interviews and focus groups are estimated to take 30-60 mins each. Depending on your level of engagement with humanitarian engineering education, you may be asked to take part in more than one interview or focus group, although this will be over multiple years. Engagement with university staff will typically take place during discussions or workshops at conferences or on university campuses, while individual interviews will be via video conferencing or face-to-face depending on availability.

Risks: Depending on your level of engagement with humanitarian engineering initiatives, there is a risk that you may be able to be identified from your responses. This may occur if you have had significant and multiple engagements with humanitarian engineering that have also be made publically available through marketing material or public channels.

Benefits: The potential benefits of this research are to influence the emerging field of humanitarian engineering education in Australia. You may not personally benefit from this research but it will contribute to future humanitarian engineering education at the ANU, the UNSW and other universities in Australia. Benefits may also flow to the researcher in terms of publications and postgraduate studies.

Implications of Participation: For students, participating in this research will not impact on your course marks or grades. Any evaluation of assessment items will be independent of marking and grading.

Confidentiality

Only the nominated researchers will have access to any material you provide. Where collected, de-identified assessment items and surveys will be kept confidential to ensure as far as possible participants will be non-identifiable for publications although de-identified quotes or pseudonym attributions may be used. Participants' names, student numbers or contact information will be not be requested or collected for surveys or assignments. Confidentiality will be protected as far as the law allows. Participates from focus group sessions are requested to maintain confidentiality of group discussions and refrain from making statements of a confidential nature or that are defamatory of any person.

Privacy Notice:

In collecting your personal information within this research, the ANU must comply with the Privacy Act 1988. The ANU Privacy Policy is available at https://policies.anu.edu.au/ppl/document/ANUP_010007 and it contains information about how a person can:

- Access or seek correction to their personal information;
- Complain about a breach of an Australian Privacy Principle by the ANU, and how the ANU will handle the complaint.

Data Storage:

Where: Once collected data will be stored in a password protected network drive at the ANU accessed only by the researchers.

How Long: Data will be kept for five years from collection or from the date of any publication arising from the research.

Handling of Data After Storage Period: After the storage period all data will archived in a de-identified format.

Queries and Concerns:

Participants can raise queries on the project by contacting the researcher Jeremy Smith at jeremy.smith@anu.edu.au or calling on 612 50468. Alternatively you can contact the postgraduate research supervisor for the work Paul Compston at paul.compston@anu.edu.au or (02) 612 58614. Participants at the UNSW can contact Fiona Johnson at f.johnson@unsw.edu.au or 9385 9769.

Ethics Committee Clearance:

The ethical aspects of this research have been approved by the ANU Human Research Ethics Committee (Protocol 2016/550). If you have any concerns or complaints about how this research has been conducted, please contact:

Ethics Manager
The ANU Human Research Ethics Committee
The Australian National University
Telephone: +61 2 6125 3427
Email: Human.Ethics.Officer@anu.edu.au

Consent Form 2016/550: Amended 2018

WRITTEN CONSENT for Participants

Student Outcomes from a Humanitarian Engineering Pathway

I have read and understood the Information Sheet you have given me about this research project, and I have had any questions and concerns about the project (listed here

____

____)

addressed to my satisfaction.

I agree to participate in the project. YES ☐ NO ☐

I agree to this interview or focus group being audio-recorded YES ☐ NO ☐ N/A ☐

I agree to my assignments from ____________________________ (enter course code(s))

being used in this research YES ☐ NO ☐ N/A ☐

I agree to my survey responses being used in this research YES ☐ NO ☐ N/A ☐

I agree to be identified in the following way within research outputs (select one):

Anonymously YES ☐ NO ☐

Pseudonym YES ☐ NO ☐

No attribution YES ☐ NO ☐

Name:……………………..……………………….

Signature:……………………………………………

Date:…………………………………………….…….

University:…………………………………….…….

Appendix II: Data Collection Tools

Introduction

The major data collection tools used in the research are provided in this Appendix. These are:

1. Anonymous profile surveys for first and third/fourth year students in the College of Engineering and Computer Science (CECS), which were used to collect a baseline from the engineering student cohort at the ANU.
2. Anonymous pre- and post-surveys completed before and after a Humanitarian Engineering international study abroad experience, such as an EWB Humanitarian Design Summit.
3. Anonymous exit (post) survey completed at the end of the Engineering for a Humanitarian Context (EfaHC) course.
4. Anonymous pre- and post-surveys completed before and after an individual or group research or design project with a Humanitarian Engineering focus.
5. Interview script questions and demographic survey used for graduate interviews.

In some cases, slight variations were made to surveys from semester to semester, and the versions included here are the final versions used. All data collection tools were approved by the ANU Human Ethics Committee as part of the ethics protocols contained in Appendix I.

1a/ CECS Student Profile Survey: First Year

Study:

S1/ What degree program are you enrolled in? ____

S2/ What major(s) are you currently,

or most likely to consider, studying? ____

S3/ What minor(s) are you currently,

or most likely to consider, studying? ____

S4/ What year are you? _______________________

S5/ What age were you when you started your current studies? ___________________

S6/ Did you have a gap year between finishing school and starting university? Yes No

S7/ Are you a member of Engineers Australia (circle one that applies)?

Yes, student member Yes, paid member No

Motivations:

M4/ From the application areas below, rate on a scale of 1 (no interest) to 4 (strong interest) which are you potentially interested in applying your engineering with when you graduate?

Application Area	**No Interest**	**Some Interest**	**Interested**	**Strong Interest**
Multi-national corporations	1	2	3	4
Entrepreneurship (start-up companies) or own business	1	2	3	4
Government or public policy	1	2	3	4
Competitive sports	1	2	3	4
Humanitarian responses, or community, not-for-profit or social organisations	1	2	3	4
Research and development (R&D)	1	2	3	4
Defence / Defence Industry	1	2	3	4
Engineering manufacturers or industrial organisations	1	2	3	4
Consultancies	1	2	3	4
Education or training	1	2	3	4
Technology or project management	1	2	3	4

A3/ Which of the following outreach activities, if any, did you take part in? For those you did take part in, rate their influence from 1 (no influence) to 4 (major influence), on your current degree choice?

Activity	**Took Part**	**No Influence**	**Some Influence**	**Influence**	**Major Influence**
School Careers Fair	Y	1	2	3	4
EWB Workshop	Y	1	2	3	4
RoboGals Workshop	Y	1	2	3	4
GET (Girls in Engineering and Technology) Set Day	Y	1	2	3	4
NYSF (National Youth Science Forum)	Y	1	2	3	4
Careers Fair	Y	1	2	3	4
ANU Open Day	Y	1	2	3	4
ANU Extension Class	Y	1	2	3	4
Other (Please State): ________________________		1	2	3	4
Other (Please State): ________________________		1	2	3	4
Other (Please State): ________________________		1	2	3	4

Past Experience:

P1/ Have you taken part in the EWB Challenge at university? Yes No

P2/ Do you have any previous qualifications since finishing school? Yes No

P2a/ If *Yes*, what is your highest level of qualification (Bachelor, Master, …)? _________________

P3/ Have you been involved in any community or volunteer work?

None — Some (between 2-5 years in total)

A little (less than 1 year) — Regularly or significant amounts (over > 5 year period)

P3a/ If *Yes*, how old were you when you first took part? __________

P3b/ If *Yes*, what locations have you volunteered in (circle all of those that apply)?

ACT — Other Urban Areas — Rural Area — Remote Area

Overseas (please give countries): ___________________________

P3c/ If *Yes*, what was the nature of the volunteering? ____

P3d/ If *Yes*, while at <u>university</u>, did or will this contribute to any of the following (circle any that apply)?

Course Credit — Work Experience

Course Requirement — Certificate (such as ANU+)

P4/ Do you have any *engineering* work experience?

None | Work experience | Internship

Previous part-time work | Current part-time work

Previous full-time work | Current full-time work

P4a/ Was any or all of this work experience volunteer (unpaid)? Yes No

P5/ Have you been involved with any study abroad programs (such as field schools, study tours or exchanges) at school or university? Yes No

P5a/ If *Yes*, what age were you for your first study abroad experience? __________

Commitments:

C1/ Have you worked while you have been at university? Yes No

C1a/ If *Yes*, what has your highest work commitment been (mark on the range below)?

0 | 10 | 20 | 30 | 40

hours / week

C1b/ If *Yes*, was this only, or mainly, during teaching breaks? Yes No

C1c/ If *Yes*, was this your main source of financial support for your studies? Yes No

C2/ During your current studies, you been involved with any student or university organisations?

Yes No

C2a/ If *Yes*, which organisations (circle all that apply):

ANUESA | Sol Invictus | EWB | ANUESA

RoboGals | Fifty50 | Engage Outreach

Residence / Hall | Spiritual / Religious Group | Learning Community

International Student Society | Sports Club / Team | Music / Arts

Research Group / Society | Online Social or Community Organisation

Other (please state): ____

C2b/ If *Yes*, how would you describe your greatest level of involvement (circle one)?

Member | Regular Contributor / Volunteer | Leadership Role

C2c/ If *Yes*, what was your highest level of regular involvement (mark on the range below)?

0 10 20 30 40

hours / week

C2d/ If *Yes*, was this only, or mainly, during teaching breaks? Yes No

C2e/ If *Yes*, while at university did or will this contribute to any of the following (circle all that apply)?

Course Credit Work Experience

Course Requirement Certificate (such as ANU+)

C3/ Are you responsible for the regular care of a family member? Yes No

Engineering Beliefs:

B1/ Use the scale of 1 (NI - not important), 2 (N -neutral), 3 (I - important) to 4 (VI - very important) to rate how important you think each of the following areas are for a professional engineer.

Area	**NI**	**N**	**I**	**VI**
Fundamental knowledge (such as maths and science)	1	2	3	4
Business skills (project management, entrepreneurship)	1	2	3	4
Research skills (conducting research, contemporary issues)	1	2	3	4
Interdisciplinary knowledge (from a non-engineering field or discipline)	1	2	3	4
Engineering Discipline knowledge (in my major area)	1	2	3	4
Professional skills (such as communication or teamwork)	1	2	3	4
Ethical practice (integrity, social responsibility, sustainable development)	1	2	3	4
Technical skills (design process, simulation, modelling, …)	1	2	3	4
Systems engineering (defining scope and problem, systems boundaries, considering lifecycles)	1	2	3	4

B2/ The following statements relate to your views of engineering and engineers. Please rate on a scale of 1 (strongly disagree) to 5 (strongly agree) your agreement with the following statements.

Statement	**SD**	**D**	**N**	**A**	**SA**
Engineers should use their skills to solve social problems	1	2	3	4	5
The engineering profession needs to be more diverse	1	2	3	4	5
it is important to me personally to have a career that involves helping people	1	2	3	4	5
In general, being an engineer is an important part of my self-image	1	2	3	4	5
I will actively use engineering to help others	1	2	3	4	5
Engineering and technology alone can solve social problems	1	2	3	4	5
Engineering can have a negative impact on society	1	2	3	4	5
It is not my responsibility to do something about improving society	1	2	3	4	5
I will be happy to be an engineer	1	2	3	4	5
Overall, being an engineer has very little to do with how I feel about myself	1	2	3	4	5
I often regret that I chose to be an engineer	1	2	3	4	5
Being an engineer is important to how I feel about myself	1	2	3	4	5
I identify with engineers	1	2	3	4	5
It is the role of engineers to contribute to improving society	1	2	3	4	5

B4/ Please rate on a scale of 1 (strongly disagree) to 5 (strongly agree) your agreement with the following statements in relation to you engineering classes.

In my engineering classes I feel	**SD**	**D**	**N**	**A**	**SA**
Frustrated	1	2	3	4	5
Angry	1	2	3	4	5
Overworked	1	2	3	4	5
Happy	1	2	3	4	5
Enthusiastic	1	2	3	4	5
Insecure	1	2	3	4	5
Fulfilled	1	2	3	4	5
Challenged	1	2	3	4	5
Motivated	1	2	3	4	5

B3/ The following statements relate to your engineering studies. Please rate on a scale of 1 (strongly disagree) to 5 (strongly agree) your agreement with the following statements. *Major* refers to your discipline major as stated in question S2.

Statement	**SD**	**D**	**N**	**A**	**SA**
I believe I will receive excellent grades in the classes in my major	1	2	3	4	5
I expect to do well in the classes in my major	1	2	3	4	5
I'm confident I can understand the most complex material presented by the instructors in the classes in my major	1	2	3	4	5
I'm certain I can understand the most difficult material taught in the classes in my major	1	2	3	4	5
I'm confident I can do an excellent job on the assignments and tests given in the classes in my major	1	2	3	4	5
I enjoy learning in my major classes	1	2	3	4	5
When I'm in classes in my major, I feel good	1	2	3	4	5
In my major classes, when we work on something, I feel interested	1	2	3	4	5
I feel comfortable studying engineering	1	2	3	4	5
I feel that I am a part of engineering	1	2	3	4	5
I feel that I am supported studying engineering	1	2	3	4	5
I feel that I am accepted studying engineering	1	2	3	4	5
I feel comfortable in this major	1	2	3	4	5
I feel that I am a part of this major	1	2	3	4	5
I feel that I am supported in this major	1	2	3	4	5
I feel that I am accepted in this major	1	2	3	4	5
I feel like I really belong at this university	1	2	3	4	5
I wish I had gone to another university instead of this one	1	2	3	4	5
I feel like there is a strong feeling of togetherness on campus	1	2	3	4	5
I really enjoy going to school at this university	1	2	3	4	5
I feel that there is a sense of community at this university/college	1	2	3	4	5
People at this university are friendly to me	1	2	3	4	5

Demographics

D1/ Are you receiving a scholarship for your degree? Yes No

D2/ For enrolment are you a (circle one): Domestic student International student

D3/ How would you characterise your average course marks (circle one)?

upper HD HD D CR P Other (please state): _______

D4/ What is your age? ____________

D5/ Please select your gender (circle one):

Female Would prefer not to specify

Male Indeterminate / Intersex / Unspecified

D6/ Is English (circle one): your first language not your first language

D7/ Other than your first language, do you know any other languages? Yes No

D7a/ If *Yes*, what other languages do you know? ____

D7b/ If *No*, have you studied any other languages? Yes No

D8/ Do you have a close family member who is or has been an engineer? Yes No

D9/ Do you have a close family member who is or has been involved with humanitarian work?

Yes No

D10/ Are you the first generation of your family to attend university? Yes No

D11/ How would you describe your cultural background? ______________________________

D12/ Where did you spend most of your time growing up? Rural Area Urban Centre

D13/ For your enrolment, are you studying (circle one)? Full Time Part Time

D14/ Did you identify as Aboriginal or Torres Strait Islander? Yes No

D15/ What has been you most common living arrangement while studying (circle one)?

Residence / Hall Shared Off-campus With family

D16/ During your studies have you been supported by ANU's Access and Inclusion Hub?

Yes No

D17/ If you have or are finishing your studies, are you in, or about to enter, employment?

Not Finishing Yes No

D17a/ If *Yes*, is this a full-time position? Yes No

1b/ CECS Student Profile Survey: 3rd/4th Year

Study:

S1/ What degree program are you enrolled in? ____

S2/ What major(s) are you currently,

or most likely to consider, studying? ____

S3/ What minor(s) are you currently,

or most likely to consider, studying? ____

S4/ What year are you? _______________________

S5/ What age were you when you started your current studies? ___________________

S6/ Did you have a year or more off between finishing school and starting university? Yes No

S7/ Are you a member of Engineers Australia (circle one that applies)?

Yes, student member   Yes, paid member   No

Past Experience:

P1/ Have you taken part in the EWB Challenge at university? Yes No

P2/ Do you have any previous qualifications since finishing school? Yes No

P2a/ If *Yes*, what is your highest level of qualification (Bachelor, Master, …)? _______________

P3/ Have you been involved in any community or volunteer work (circle one that applies)?

None   Some (between 2-5 years in total)

A little (less than 1 year)   Regularly or significant amounts (over > 5 year period)

P3a/ If *Yes*, how old were you when you first took part? _________

P3b/ If *Yes*, what locations have you volunteered in (circle all of those that apply)?

ACT   Other Urban Areas   Rural Area   Remote Area

Overseas (please give countries): ________________________

P3c/ If *Yes*, what was the nature of the volunteering? ___________________________________

P3d/ If *Yes*, while at <u>university</u>, did or will this contribute to any of the following (circle any that apply)?

Course Credit   Work Experience

Course Requirement   Certificate (such as ANU+)

P4/ Do you have any <u>*engineering*</u> work experience (circle all those that apply)?

None	Work experience	Internship
Previous part-time work	Current part-time work	
Previous full-time work	Current full-time work	

P4a/ Was any or all of this work experience volunteer (unpaid)? Yes No

P5/ Have you been involved with any study abroad programs
(such as field schools, study tours or exchanges) at school or university? Yes No

P5a/ If *Yes*, what age were you for your first study abroad experience? __________

P5b/ If yes, which of the following international experiences have you completed while at <u>university</u> and during what year of your studies did you complete them (circle Y if you have completed and write the university year when you completed any, such as *first* or *third*)?

International Experience	**Completed**	**When (Year)**
EWB Summit (State location) : _________________________	Y	___________
GlobeX (China)	Y	___________
IARU Course (location) : ______________________________	Y	___________
Exchange (university) : _______________________________	Y	___________
Other (please state): _______________________________	Y	___________

Commitments:

C1/ Have you worked while you have been at university? Yes No

C1a/ If *Yes*, what has your highest work commitment been (mark on the line below)?

0 10 20 30 40

hours / week

C1b/ If *Yes*, was this only, or mainly, during teaching breaks? Yes No

C1c/ If *Yes*, was this your main source of financial support for your studies? Yes No

C2/ During your current studies, have you been involved with any student or university organisations? Yes No

C2a/ If *Yes*, which organisations (circle all that apply):

ANUESA	Sol Invictus	EWB	ANUSA
RoboGals	Fifty50	Engage Outreach	
Residence / Hall	Spiritual / Religious Group	Learning Community	
International Student Society	Sports Club / Team	Music / Arts	
Research Group / Society	Online Social or Community Organisation		

Other (please state): ____

C2b/ If *Yes*, how would you describe your greatest level of involvement (circle one)?

Member   Regular Contributor / Volunteer   Leadership Role

C2c/ If *Yes*, what was your highest level of regular involvement (mark on the line below)?

0   10   20   30   40

hours / week

C2d/ If *Yes*, was this only, or mainly, during teaching breaks?   Yes   No

C2e/ If *Yes*, while at university did or will this contribute to any of the following (circle all that apply)?

Course Credit   Work Experience

Course Requirement   Certificate (such as ANU+)

C3/ Are you responsible for the regular care of a family member?   Yes   No

Motivations:

M4/ From the application areas below, rate on a scale of 1 (no interest) to 4 (strong interest) which are you potentially interested in applying your engineering with when you graduate?

Application Area	**No Interest**	**Some Interest**	**Interested**	**Strong Interest**
Multi-national corporations	1	2	3	4
Entrepreneurship (start-up companies) or own business	1	2	3	4
Government or public policy	1	2	3	4
Competitive sports	1	2	3	4
Humanitarian responses, or community, not-for-profit or social organisations	1	2	3	4
Research and development (R&D)	1	2	3	4
Defence / Defence Industry	1	2	3	4
Engineering manufacturers or industrial organisations	1	2	3	4
Consultancies	1	2	3	4
Education or training	1	2	3	4
Technology or project management	1	2	3	4

Engineering Beliefs:

B5/ If you are doing a double degree (including a flexible double), please rate on a scale of 1 (strongly disagree) to 5 (strongly agree) your agreement with the following statements.

Statement	**SD**	**D**	**N**	**A**	**SA**
I identify more with my non-engineering degree (if studying a double degree)	1	2	3	4	5
I expect to predominantly work in my engineering field	1	2	3	4	5
I feel more accepted in my engineering degree	1	2	3	4	5

B1/ Use the scale of 1 (NI - not important), 2 (N -neutral), 3 (I - important) to 4 (VI - very important) to rate how important you think each of the following areas are for a professional engineer.

Area	NI	N	I	VI
Fundamental knowledge (such as maths and science)	1	2	3	4
Business skills (project management, entrepreneurship)	1	2	3	4
Research skills (conducting research, contemporary issues)	1	2	3	4
Interdisciplinary knowledge (from a non-engineering field or discipline)	1	2	3	4
Engineering Discipline knowledge (in my major area)	1	2	3	4
Professional skills (such as communication or teamwork)	1	2	3	4
Ethical practice (integrity, social responsibility, sustainable development)	1	2	3	4
Technical skills (design process, simulation, modelling, …)	1	2	3	4
Systems engineering (defining scope and problem, systems boundaries, considering lifecycles)	1	2	3	4

B2/ The following statements relate to your views of engineering and engineers. Please rate on a scale of 1 (strongly disagree) to 5 (strongly agree) your agreement with the following statements.

Statement	SD	D	N	A	SA
Engineers should use their skills to solve social problems	1	2	3	4	5
The engineering profession needs to be more diverse	1	2	3	4	5
it is important to me personally to have a career that involves helping people	1	2	3	4	5
In general, being an engineer is an important part of my self-image	1	2	3	4	5
I will actively use engineering to help others	1	2	3	4	5
Engineering and technology alone can solve social problems	1	2	3	4	5
Engineering can have a negative impact on society	1	2	3	4	5
It is not my responsibility to do something about improving society	1	2	3	4	5
I will be happy to be an engineer	1	2	3	4	5
Overall, being an engineer has very little to do with how I feel about myself	1	2	3	4	5
I often regret that I chose to be an engineer	1	2	3	4	5
Being an engineer is important to how I feel about myself	1	2	3	4	5
I identify with engineers	1	2	3	4	5
It is the role of engineers to contribute to improving society	1	2	3	4	5

B3/ The following statements relate to your engineering studies. Please rate on a scale of 1 (strongly disagree) to 5 (strongly agree) your agreement with the following statements. *Major* refers to your discipline major as stated in question S2.

Statement	**SD**	**D**	**N**	**A**	**SA**
I believe I will receive excellent grades in the classes in my major	1	2	3	4	5
I expect to do well in the classes in my major	1	2	3	4	5
I'm confident I can understand the most complex material presented by the instructors in the classes in my major	1	2	3	4	5
I'm certain I can understand the most difficult material taught in the classes in my major	1	2	3	4	5
I'm confident I can do an excellent job on the assignments and tests given in the classes in my major	1	2	3	4	5
I enjoy learning in my major classes	1	2	3	4	5
When I'm in classes in my major, I feel good	1	2	3	4	5
In my major classes, when we work on something, I feel interested	1	2	3	4	5
I feel comfortable studying engineering	1	2	3	4	5
I feel that I am a part of engineering	1	2	3	4	5
I feel that I am supported studying engineering	1	2	3	4	5
I feel that I am accepted studying engineering	1	2	3	4	5
I feel comfortable in this major	1	2	3	4	5
I feel that I am a part of this major	1	2	3	4	5
I feel that I am supported in this major	1	2	3	4	5
I feel that I am accepted in this major	1	2	3	4	5
I feel like I really belong at this university	1	2	3	4	5
I wish I had gone to another university instead of this one	1	2	3	4	5
I feel like there is a strong feeling of togetherness on campus	1	2	3	4	5
I really enjoy going to school at this university	1	2	3	4	5
I feel that there is a sense of community at this university/college	1	2	3	4	5
People at this university are friendly to me	1	2	3	4	5

B4/ Please rate on a scale of 1 (strongly disagree) to 5 (strongly agree) your agreement with the following statements in relation to you engineering classes.

In my engineering classes I feel	**SD**	**D**	**N**	**A**	**SA**
Frustrated	1	2	3	4	5
Angry	1	2	3	4	5
Overworked	1	2	3	4	5
Happy	1	2	3	4	5
Enthusiastic	1	2	3	4	5
Insecure	1	2	3	4	5
Fulfilled	1	2	3	4	5
Challenged	1	2	3	4	5
Motivated	1	2	3	4	5

Demographics

D1/ Are you receiving a scholarship for your degree? Yes No

D2/ For enrolment are you a (circle one): Domestic student International student

D3/ How would you characterise your average course marks (circle one)?

upper HD HD D CR P Other (please state): _______

D4/ What is your age? ____________

D5/ Please select your gender (circle one):

Female Would prefer not to specify

Male Indeterminate / Intersex / Unspecified

D6/ Is English (circle one): your first language not your first language

D7/ Other than your first language, do you know any other languages? Yes No

D7a/ If *Yes*, what other languages do you know? ____

D7b/ If *No*, have you studied any other languages? Yes No

D8/ Do you have a close family member who is or has been an engineer? Yes No

D9/ Do you have a close family member who is or has been involved with humanitarian work?

Yes No

D10/ Are you the first generation of your family to attend university? Yes No

D11/ How would you describe your cultural background? ______________________________

D12/ Where did you spend most of your time growing up (circle one)? Rural Area Urban Centre

D13/ For your enrolment, are you studying (circle one)? Full Time Part Time

D14/ Did you identify as Aboriginal or Torres Strait Islander? Yes No

D15/ What has been you most common living arrangement while studying (circle one)?

Residence / Hall Shared Off-campus With family

D16/ During your studies have you been supported by ANU's Access and Inclusion Hub?

Yes No

D17/ If you are finishing your studies, are you in, or about to enter, employment (circle one)?

Not Finishing Studies Yes No

D17a/ If *Yes*, is this a full-time position? Yes No

2a/ CECS International Experience: Pre-Survey

Background and Study:

S1/ What degree program are you enrolled in? ____

S2/ What major(s) are you currently,

or most likely to consider, studying? ____

S3/ What minor(s) are you currently,

or most likely to consider, studying? ____

S4/ What year are you? ______________________

S5/ What age were you when you started your current studies? __________________

S6/ Did you have a year or more off between finishing school and starting university? Yes No

International Background:

I1/ What international experience are you about to undertake (circle one)?

EWB Design Summit GREEN Program Enabled Futures Study Trip

GlobeX Unbound Academy Exchange (semester abroad)

IARU Course (if *Yes* please state which course): ______________________________

Other (please state): _____________________________________

I2/ When will you be travelling (month(s) and year)? ____________________________________

I3/ What country (or countries) will you be visiting? ___________________________________

I4/ Have you been to the country you are visiting on this experience before? Yes No

I5/ Is attending this experience the first time you have travelled overseas? Yes No

I6/ Do you know the language of the country you are visiting on this experience? Yes No

I8/ How is this most recent experience contributing to your degree requirements (circle one)?

Work Experience (ENGN3100) Engineering Course Credit (such as ENGN course)

For-credit internship (ENGN3200) Research Project (such as ENGN4200 or R&D)

Other Course Credit (non-ENGN course) Not Contributing

Other: ____

I7/ Have you been involved with any previous study abroad programs

(such as field schools, study tours or exchanges) at school or university? Yes No

I7a/ If *Yes*, what age were you for your first study abroad experience? __________

I9/ Are you receiving a scholarship to support your involvement in this experience? Yes No

I9a/ If *Yes*, would you have still taken part if you were not receiving a scholarship? Yes No

I9b/ If *Yes*, what is the source of your scholarship (circle one)?

NCP CECS Other: _________________

I10/ Are you using OS Help to support this international experience?

Yes No, but Eligible Not Eligible

Motivations:

M3/ For each of the motivations below, rate on a scale of 1 (no motivation) to 4 (strong motivator) how each contributed to your motivation for undertaking this international experience?

Motivation	No Motivation	Some Motivation	Motivator	Strong Motivator
Inspired by my personal experiences	1	2	3	4
To gain experience in professional skills (team-work, communication, …)	1	2	3	4
To meet like-minded people	1	2	3	4
Enhance employment, career or job prospects	1	2	3	4
Application of engineering	1	2	3	4
Others suggested it	1	2	3	4
To gain work experience	1	2	3	4
To challenge myself	1	2	3	4
To try something new	1	2	3	4
To see the outcomes of my engineering	1	2	3	4
To have an international experience	1	2	3	4
To have fun	1	2	3	4
To work on complex problems	1	2	3	4
To gain more in-depth knowledge related to my discipline major	1	2	3	4
To count as course credit	1	2	3	4
To study will a friend or peer	1	2	3	4
To make a contribution to society	1	2	3	4
For a research project (ENGN4200 or equivalent)	1	2	3	4

M3a/ If other motivations please state: ____

M1/ What are you hoping to gain most from this international experience?

M2/ Are you worried about any aspects of this international experience, and if so what?

M4/ From the application areas below, rate on a scale of 1 (no interest) to 4 (strong interest) which are you potentially interested in applying your engineering with when you graduate?

Application Area	**No Interest**	**Some Interest**	**Interested**	**Strong Interest**
Multi-national corporations	1	2	3	4
Entrepreneurship (start-up companies) or own business	1	2	3	4
Government or public policy	1	2	3	4
Competitive sports	1	2	3	4
Humanitarian responses, or community, not-for-profit or social organisations	1	2	3	4
Research and development (R&D) / postgraduate studies	1	2	3	4
Defence / Defence Industry	1	2	3	4
Engineering manufacturers or industrial organisations	1	2	3	4
Consultancies	1	2	3	4
Education or training	1	2	3	4
Technology or project management	1	2	3	4

M5/ For each of the statements below, rate on a scale of 1 (strongly disagree) to 5 (strongly agree) which you are hoping to achieve from your international experience:

Statement	**SD**	**D**	**N**	**A**	**SA**
I expect to learn new engineering skills and knowledge	1	2	3	4	5
I expect to make a positive contribution to the country I am visiting	1	2	3	4	5
I expect to use or apply my engineering skills and knowledge	1	2	3	4	5
I expect to be able to communicate with everyone I meet	1	2	3	4	5
I expect this will be relevant for my current studies	1	2	3	4	5
My presence will have a negative impact on the country I visit	1	2	3	4	5
I expect to learn about the country I am visiting	1	2	3	4	5
I expect to learn about my role as an engineer	1	2	3	4	5
I expect to gain global competencies or knowledge	1	2	3	4	5

Commitments:

C1/ Have you worked while you have been at university? Yes No

C1a/ If *Yes*, what has your highest work commitment been (mark on the range below)?

0 10 20 30 40

hours / week

C1b/ If *Yes*, was this only, or mainly, during teaching breaks? Yes No

C1c/ If *Yes*, was this your main source of financial support for your studies? Yes No

C2/ During your current studies, have you been involved with any student or university organisations? Yes No

C2a/ If *Yes*, which organisations (circle all that apply):

ANUESA Fifty50 Sol Invictus ANUSA

RoboGals NAE GCSP EWB Engage Outreach

Residence / Hall Spiritual / Religious Group Learning Community

International Student Society Sports Club / Team Music / Arts

Research Group / Society Online Social or Community Organisation

Other (please state): ____

C2b/ If *Yes*, how would you describe your greatest level of involvement (circle one)?

Member Regular Contributor / Volunteer Leadership Role

C2c/ If *Yes*, what was your highest level of regular involvement (mark on the range below)?

0   10   20   30   40

hours / week

C2d/ If *Yes*, was this only, or mainly, during teaching breaks? Yes No

C2e/ If *Yes*, while at university did or will this contribute to any of the following (circle all that apply)?

Course Credit	Work Experience
Course Requirement	Certificate (such as ANU+)

C3/ Are you responsible for the regular care of a family member? Yes No

Past Experience:

P1/ Have you taken part in the EWB Challenge at university? Yes Not Sure No

P2/ Do you have any previous qualifications since finishing school? Yes No

P2a/ If *Yes*, what is your highest level of qualification (Bachelor, Master, …)? ________________

P3/ Have you been involved in any community or volunteer work?

None	Some (between 2-5 years in total)
A little (less than 1 year)	Regularly or significant amounts (over > 5 year period)

P3a/ If *Yes*, how old were you when you first took part? _________

P3b/ If *Yes*, what locations have you volunteered in (circle all of those that apply)?

ACT   Other Urban Areas   Rural Area   Remote Area

Overseas (please give countries): _________________________

P3c/ If *Yes*, what was the nature of the volunteering? _____________________________________

P3d/ If *Yes*, while at university, did or will this contribute to any of the following (circle any that apply)?

Course Credit	Work Experience
Course Requirement	Certificate (such as ANU+ or NAE GCSP)

P4/ Do you have any ***engineering*** work experience (circle all those that apply)?

None	Work experience	Internship
Previous part-time work	Current part-time work	
Previous full-time work	Current full-time work	

P4a/ Was any or all of this work experience volunteer (unpaid)? Yes No

B1/ Use the scale of 1 (NI - not important), 2 (N -neutral), 3 (I - important) to 4 (VI - very important) to rate how important you think each of the following areas are for a professional engineer.

Area	**NI**	**N**	**I**	**VI**
Fundamental knowledge (such as maths and science)	1	2	3	4
Business skills (project management, entrepreneurship)	1	2	3	4
Research skills (conducting research, contemporary issues)	1	2	3	4
Interdisciplinary knowledge (from a non-engineering field or discipline)	1	2	3	4
Engineering Discipline knowledge (in my major area)	1	2	3	4
Professional skills (such as communication or teamwork)	1	2	3	4
Ethical practice (integrity, social responsibility, sustainable development)	1	2	3	4
Technical skills (design process, simulation, modelling, …)	1	2	3	4
Systems engineering (defining scope and problem, systems boundaries, considering lifecycles)	1	2	3	4

B2/ The following statements relate to your views of engineering and engineers. Please rate on a scale of 1 (strongly disagree) to 5 (strongly agree) your agreement with the following statements.

Statement	**SD**	**D**	**N**	**A**	**SA**
Engineers should use their skills to solve social problems	1	2	3	4	5
The engineering profession needs to be more diverse	1	2	3	4	5
it is important to me personally to have a career that involves helping people	1	2	3	4	5
In general, being an engineer is an important part of my self-image	1	2	3	4	5
I will actively use engineering to help others	1	2	3	4	5
Engineering and technology alone can solve social problems	1	2	3	4	5
Engineering can have a negative impact on society	1	2	3	4	5
It is not my responsibility to do something about improving society	1	2	3	4	5
I will be happy to be an engineer	1	2	3	4	5
Overall, being an engineer has very little to do with how I feel about myself	1	2	3	4	5
I often regret that I chose to be an engineer	1	2	3	4	5
Being an engineer is important to how I feel about myself	1	2	3	4	5
I identify with engineers	1	2	3	4	5
It is the role of engineers to contribute to improving society	1	2	3	4	5

Demographics

D1/ Are you receiving a scholarship for your degree? Yes No

D2/ For enrolment are you a (circle one): Domestic student International student

D3/ How would you characterise your average course marks (circle one)?

upper HD HD D CR P Other (please state): _______

D4/ What is your age? ____________

D5/ Please select your gender (circle one):

Female Would prefer not to specify

Male Indeterminate / Intersex / Unspecified

D6/ Is English (circle one): your first language not your first language

D7/ Other than your first language, do you know any other languages? Yes No

D7a/ If *Yes*, what other languages do you know? ____

D7b/ If *No*, have you studied any other languages? Yes No

D8/ Do you have a close family member who is or has been an engineer? Yes No

D9/ Do you have a close family member who is or has been involved with humanitarian work?

Yes No

D10/ Are you the first generation of your family to attend university? Yes No

D12/ Where did you spend most of your time growing up? Rural Area Urban Centre

D13/ For your enrolment, are you studying (circle one)? Full Time Part Time

D14/ Did you identify as Australian Aboriginal or Torres Strait Islander?

Yes No

D15/ What has been you most common living arrangement while studying (circle one)?

Residence / Hall Shared Off-campus With family

D16/ During your studies have you been supported by ANU's Access and Inclusion Hub?

Yes No

The following questions relate specifically to the *EWB Humanitarian Design Summit*.

E1/ What is your understanding or definition of *humanitarian engineering*?

E2/ For each of the motivations below, rate on a scale of 1 (no motivation) to 4 (strong motivator) how each contributed to your motivation for undertaking the EWB Summit?

Motivation	No Motivation	Some Motivation	Motivator	Strong Motivator
To work with people	1	2	3	4
Sense of responsibility or duty	1	2	3	4
Interested in humanitarian engineering	1	2	3	4
To work directly with and help people who may be disadvantaged				
To undertake the *Engineering for a Humanitarian Context* course	1	2	3	4
Only international experience available	1	2	3	4

E2a/ If other motivations please state: ____

E3/ If you are using the EWB Summit for the *Engineering for a Humanitarian Context* course, what was your primary motivation for enrolling in the course (circle one)?

A. convenience
B. interested in humanitarian engineering
C. just need one course to finish studies
D. interested in application of engineering to real-world problems
E. reduced course load for one semester
F. background for research project (ENGN4200, R&D or equivalent)
G. requirement to receive scholarship
H. other (please state): ______________________________

E4/ Have you considered basing a research project (ENGN4200 , R&D or equivalent) on humanitarian engineering issues (circle one)?

yes no not sure already am

2b/ CECS International Experience: Post-Survey

In the following questions, the term '*international experience*' refers to your most recent international experience.

Study:

S1/ What degree program are you enrolled in? ______________________________

S2/ What major(s) are you currently,

or most likely to consider, studying? ______________________________

S3/ What minor(s) are you currently,

or most likely to consider, studying? ______________________________

S4/ What year are you? ____________________

S5/ What age were you when you started your current studies? ________________

S6/ Did you have a gap year between finishing school and starting university? Yes No

S7/ Are you a member of Engineers Australia (circle one that applies)?

Yes, student member Yes, paid member No

International Background:

I1/ What international experience did you just undertake (circle one)?

EWB Design Summit GlobeX Exchange (semester abroad)

IARU Course (if *Yes* please state which course): ________________________

Other (please state): ________________________

I2/ When did you travel (month(s) and year)? ______________________________

I3/ What country (or countries) did you visit? ______________________________

I8/ How did this experience contribute to your degree requirements (circle all those that apply)?

Work Experience (ENGN3100) Engineering Course Credit (such as ENGN course)

For-credit internship (ENGN3200) Research Project (such as ENGN4200 or R&D)

Other Course Credit (non-ENGN course) Not Contributing

Other: ______________________________

Outcomes:

O1/ What do you consider the most important learning from this experience and why?

O2/ What contributions to your engineering studies did this experience make, if any?

O3/ What did you find most challenging about this experience (if anything) and why?

O4/ What impact do you think this experience has had on your future engineering practice?

1. very negative impact (ie not sure if I want to continue with engineering study)
2. negative impact (ie waste of time and should have done something else)
3. somewhat negative impact
4. no or little impact
5. somewhat positive impact
6. positive impact
7. very positive impact

O5/ Rate the learning gains you made from this experience in the areas below from 1 (no gain) to 4 (significant gain):

Learning Gain	None	Minor	Some	Significant
Application of engineering to the real-world	1	2	3	4
Communication skills	1	2	3	4
Adaptability	1	2	3	4
Creativity	1	2	3	4
Cross-cultural awareness	1	2	3	4
Teamwork skills	1	2	3	4
To my discipline major	1	2	3	4
To the systems engineering core	1	2	3	4
Ethical practice	1	2	3	4
Incorporating sustainability into engineering	1	2	3	4
Engineering design	1	2	3	4
Engaging with users or stakeholders	1	2	3	4
Ability to work internationally	1	2	3	4
Ability to work on complex problems	1	2	3	4
Ability to incorporate social factors into engineering	1	2	3	4

O6/ Has this experience contributed to your employment preferences? Are you more likely to seek employment in:

Application Area	Less Likely	A Little Less Likely	The Same	A Little More Likely	More Likely
Multi-national corporations	1	2	3	4	5
Entrepreneurship (start-up companies) or own business	1	2	3	4	5
Government or public policy	1	2	3	4	5
Competitive sports	1	2	3	4	5
Humanitarian responses, or community, not-for-profit or social organisations	1	2	3	4	5
Research and development (R&D)	1	2	3	4	5
Defence / Defence Industry	1	2	3	4	5
Engineering manufacturers or industrial organisations	1	2	3	4	5
Consultancies	1	2	3	4	5
Education or training	1	2	3	4	5
Technology or project management	1	2	3	4	5

O7/ For this experience please rate the following statements on a scale of 1 (strongly disagree) to 5 (strongly agree):

Statement	SD	D	N	A	SA
I learnt new engineering skills and knowledge	1	2	3	4	5
I made a positive contribution to the country I was visiting	1	2	3	4	5
I used or applied my engineering skills or knowledge	1	2	3	4	5
I was able to communicate with everyone I met	1	2	3	4	5
This was relevant for my current studies	1	2	3	4	5
My presence had a negative impact on the country	1	2	3	4	5
I learnt about the country I was visiting	1	2	3	4	5
I learnt about my role as an engineer	1	2	3	4	5
I am more likely to find employment	1	2	3	4	5
I am more motivated to complete my studies	1	2	3	4	5
I am more motivated to be an engineer	1	2	3	4	5
I can better connect my studies to the application of engineering knowledge	1	2	3	4	5
I made new friends	1	2	3	4	5
I had a sense of individual achievement	1	2	3	4	5

Engineering Beliefs

B1/ Use the scale of 1 (NI - not important), 2 (N -neutral), 3 (I - important) to 4 (VI - very important) to rate how important you think each of the following areas are for a professional engineer.

Area	NI	N	I	VI
Fundamental knowledge (such as maths and science)	1	2	3	4
Business skills (project management, entrepreneurship)	1	2	3	4
Research skills (conducting research, contemporary issues)	1	2	3	4
Interdisciplinary knowledge (from a non-engineering field or discipline)	1	2	3	4
Engineering Discipline knowledge (in my major area)	1	2	3	4
Professional skills (such as communication or teamwork)	1	2	3	4
Ethical practice (integrity, social responsibility, sustainable development)	1	2	3	4
Technical skills (design process, simulation, modelling, …)	1	2	3	4
Systems engineering (defining scope and problem, systems boundaries, considering lifecycles)	1	2	3	4

B2/ The following statements relate to your views of engineering and engineers. Please rate on a scale of 1 (strongly disagree) to 5 (strongly agree) your agreement with the following statements.

Statement	SD	D	N	A	SA
Engineers should use their skills to solve social problems	1	2	3	4	5
The engineering profession needs to be more diverse	1	2	3	4	5
it is important to me personally to have a career that involves helping people	1	2	3	4	5
In general, being an engineer is an important part of my self-image	1	2	3	4	5
I will actively use engineering to help others	1	2	3	4	5
Engineering and technology alone can solve social problems	1	2	3	4	5
Engineering can have a negative impact on society	1	2	3	4	5
It is not my responsibility to do something about improving society	1	2	3	4	5
I will be happy to be an engineer	1	2	3	4	5
Overall, being an engineer has very little to do with how I feel about myself	1	2	3	4	5
I often regret that I chose to be an engineer	1	2	3	4	5
Being an engineer is important to how I feel about myself	1	2	3	4	5
I identify with engineers	1	2	3	4	5
It is the role of engineers to contribute to improving society	1	2	3	4	5

B4/ Please rate on a scale of 1 (strongly disagree) to 5 (strongly agree) your agreement with the following statements in relation to your engineering classes

In my engineering classes I feel	SD	D	N	A	SA
Frustrated	1	2	3	4	5
Angry	1	2	3	4	5
Overworked	1	2	3	4	5
Happy	1	2	3	4	5
Enthusiastic	1	2	3	4	5
Insecure	1	2	3	4	5
Fulfilled	1	2	3	4	5
Challenged	1	2	3	4	5
Motivated	1	2	3	4	5

Demographics

D1/ Are you receiving a scholarship for your degree? Yes No

D2/ For enrolment are you a (circle one): Domestic student International student On Exchange

D3/ How would you characterise your average course marks (circle one)?

upper HD   HD   D   CR   P   Other (please state): _______

D4/ What is your age? ____________

D5/ Please select your gender (circle one):

Female   Would prefer not to specify

Male   Indeterminate / Intersex / Unspecified

D6/ Is English (circle one):   your first language   not your first language

D7/ Other than your first language, do you know any other languages?   Yes   No

D7a/ If *Yes*, what other languages do you know? ____

D7b/ If *No*, have you studied any other languages?   Yes   No

D8/ Do you have a close family member who is or has been an engineer?   Yes   No

D9/ Do you have a close family member who is or has been involved with humanitarian work?

Yes   No

D10/ Are you the first generation of your family to attend university?   Yes   No

D12/ Where did you spend most of your time growing up?   Rural Area   Urban Centre

D13/ For your enrolment, are you studying (circle one)?   Full Time   Part Time

D14/ Did you identify as Aboriginal or Torres Strait Islander?   Yes   No

D15/ What has been you most common living arrangement while studying (circle one)?

Residence / Hall   Shared Off-campus   With family

D16/ During your studies have you been supported by ANU's Access and Inclusion Hub?

Yes   No

In the following questions, the term '*international experience*' refers to your most recent international experience, unless otherwise stated.

A1/ Has your understanding or definition of *humanitarian engineering* changed from this experience? If so, in what ways?

A2a/ If you are considering or currently doing a research project on humanitarian engineering, has this international experience helped or contributed to your project or preparation? If so, how?

A3/ Do you have any other comments about your international experience or Humanitarian Engineering at ANU?

A6/ Would you like to undertake more humanitarian engineering experiences or courses in your studies? Yes No

A6a/ If *Yes*, how would you rate your interest in the following humanitarian engineering experiences, courses or opportunities from 1 (not interested) to 4 (very interested)

Experience / Opportunity	**Not Interested**	**Neutral**	**Interested**	**Very Interested**
For-credit courses on humanitarian engineering	1	2	3	4
Projects in existing courses on humanitarian engineering	1	2	3	4
Courses on development studies or approaches or humanitarian work	1	2	3	4
Courses or projects with non-engineering students	1	2	3	4
Short-term (less than 1 month) international experiences	1	2	3	4
Medium-term (1-6 month) international experiences	1	2	3	4
Short-term (less than 1 month) experiences in Australia	1	2	3	4
Medium-term (1-6 month) experiences in Australia	1	2	3	4
Work experience opportunities or internships	1	2	3	4
A minor in humanitarian engineering	1	2	3	4
A major in humanitarian engineering	1	2	3	4
A masters in humanitarian engineering	1	2	3	4

3/ CECS EfaHC: Exit Survey

The following questions refer to the Engineering for a Humanitarian Context (EfaHC) course.

AQ/ If you used an international experience (such as the EWB Summit), as part of the EfaHC course, please rate the following statements from 1 (strongly disagree) to 5 (strongly agree):

Statement	N/R	SD	D	N	A	SA
The course helped me connect theory to my experience overseas	n/r	1	2	3	4	5
Assignments helped me reflect on my international experience	n/r	1	2	3	4	5
I feel I gained more learning from the international experience through my involvement in the course	n/r	1	2	3	4	5
The pre-workshop was relevant and useful background for the international experience	n/r	1	2	3	4	5
The assignments were relevant for the international experience	n/r	1	2	3	4	5
I felt the assignments were unnecessary and took time away from the international experience	n/r	1	2	3	4	5
I had the necessary support to complete the course and its assignments	n/r	1	2	3	4	5
The post-workshop was relevant and supported reflection on the international experience	n/r	1	2	3	4	5

Threshold Capabilities
For questions T1 and T2, a *threshold capability* is the capability (or ability) to apply the stated threshold to previously unseen problems.

T1/ Referring to the capability *to take account of social factors in engineering designs*, please rate the following statements from 1 (strongly disagree) to 5 (strongly agree):

Statement	**SD**	**D**	**N**	**A**	**SA**
On the EWB Summit I developed the capability to take account of social factors in engineering designs	1	2	3	4	5
This learning transformed my thinking about engineering design	1	2	3	4	5
This learning transformed my thinking about the kind of engineer I hope to be	1	2	3	4	5
This learning challenged my previous assumptions	1	2	3	4	5
I needed to commit much time for this learning	1	2	3	4	5
The capability is still challenging for me	1	2	3	4	5
Learning to communicate with people from outside engineering or other cultures was challenging	1	2	3	4	5
Understanding the meaning of engineering practice was challenging	1	2	3	4	5
Understanding the meaning of humanitarian engineering was challenging	1	2	3	4	5
Dealing with loosely defined problems was challenging	1	2	3	4	5

T2/ Please rate the extent to which each of the following factors influenced your development of the capability *to take account of social factors in engineering designs*, where:

1 = Strongly hindered (SH) your development of the capability
2 = Hindered (H) your development of the capability
3 = Weakly hindered (WH) your development of the capability
4 = Neutral (N), neither hindered or supported your development of the capability
5 = Weakly supported (WS) your development of the capability
6 = Supported (S) your development of the capability
7 = Strongly supported (SS) your development of the capability
Leave blank if not relevant

Factor	**SH**	**H**	**WH**	**N**	**WS**	**S**	**SS**
The EWB Summit community visit / home-stay	1	2	3	4	5	6	7
Structured workshops during the EWB Summit	1	2	3	4	5	6	7
Opportunity to learn from peers on the EWB Summit	1	2	3	4	5	6	7
Provided reading material and resources	1	2	3	4	5	6	7
Opportunity to practice or apply existing knowledge	1	2	3	4	5	6	7
Opportunity to practice or apply new knowledge from the EWB Summit	1	2	3	4	5	6	7
Support to reflect on your learning	1	2	3	4	5	6	7
The number of students on the EWB Summit	1	2	3	4	5	6	7
Your non-study time commitments	1	2	3	4	5	6	7
Your time management	1	2	3	4	5	6	7
Facilitators on the EWB Summit	1	2	3	4	5	6	7
Developing and presenting a concept / prototype	1	2	3	4	5	6	7
Pre- and post-workshops	1	2	3	4	5	6	7
Assignments for the course	1	2	3	4	5	6	7

T2a/ Did any other factor(s) or action(s) significantly hinder or support your development of the capability t*o take account of social factors in engineering designs*? If so, please state:

____

____

4a/ CECS Research: Pre-Survey

Unless otherwise stated questions mentioning your *experience* are referring to your upcoming research project.

Study:

S1/ What degree program are you enrolled in? ____

S2/ What major(s) are you currently,

or most likely to consider, studying? ____

S3/ What minor(s) are you currently,

or most likely to consider, studying? ____

S4/ What year are you? _________________________

S5/ What age were you when you started your current studies? _____________________

S6/ Did you have a gap year between finishing school and starting university? Yes No

S8/ What research experience are you starting (circle one)?

ENGN4200 ENGN4712 ENGN2706 ENGN2707 ENGN3712 ENGN4221

Other (please state): ____

S9/ Does your project have an external partner organisation(s)? Yes No

S9a/ If *yes* who is the partner(s)? ____

Past Experience:

P1/ Have you taken part in the EWB Challenge at university? Yes No

P2/ Do you have any previous qualifications since finishing school? Yes No

P2a/ If *Yes*, what is your highest level of qualification (Bachelor, Master, …)? ________________

P4/ Do you have any *engineering* work experience (circle all that apply)?

None | Work experience | Internship

Previous part-time work | Current part-time work

Previous full-time work | Current full-time work

P4a/ Was any or all of this work experience volunteer (unpaid)? Yes No

P3/ Have you been involved in any community or volunteer work (circle one)?

None   Some (between 2-5 years in total)

A little (less than 1 year)   Regularly or significant amounts (over > 5 year period)

P3a/ If *Yes*, how old were you when you first took part? _________

P3b/ If *Yes*, what locations have you volunteered in (circle all of those that apply)?

ACT   Other Urban Areas   Rural Area   Remote Area

Overseas (please give countries): _________________________

P3c/ If *Yes*, what was the nature of the volunteering? _____________________________________

P3d/ If *Yes*, while at university, has this contribute to any of the following (circle any that apply)?

Course Credit   Work Experience

Course Requirement   Certificate (such as ANU+)

P5/ Have you been involved with any study abroad programs

(such as field schools, study tours or exchanges) at school or university?   Yes   No

P5a/ If *Yes*, what age were you for your first study abroad experience? __________

P5b/ If yes, which of the following international experiences have you completed while at university and during what year of your studies did you complete them (circle Y if you have completed and write the university year when you completed any, such as *first* or *third*)?

International Experience	**When (Year)**
EWB Summit (State location) : _____________________________	___________
GlobeX (China)	___________
IARU Course (location) : __________________________________	___________
Exchange (university) : ___________________________________	___________
Other 1 (please state): ___________________________________	___________
Other 2 (please state): ___________________________________	___________

Commitments:

C1/ Have you worked while you have been at university? Yes No

C1a/ If *Yes*, what has your highest work commitment been (mark on the range below)?

0 10 20 30 40

hours / week

C1b/ If *Yes*, was this only, or mainly, during teaching breaks? Yes No

C1c/ If *Yes*, was this your main source of financial support for your studies? Yes No

C2/ Have you been involved with any student or university organisations? Yes No

C2a/ If *Yes*, which organisations (circle any that apply):

ANUESA Sol Invictus EWB ANUSA

RoboGals Fifty50 Engage Outreach

Residence / Hall Spiritual / Religious Group Learning Community

International Student Society Sports Club / Team Music / Arts

Research Group / Society Online Social or Community Organisation

Other (please state): ____

C2b/ If *Yes*, how would you describe your greatest level of involvement (circle one)?

Member Regular Contributor / Volunteer Leadership Role

C2c/ If *Yes*, what was your highest level of regular involvement (mark on the range below)?

0 10 20 30 40

hours / week

C2d/ If *Yes*, was this only, or mainly, during teaching breaks? Yes No

C2e/ If *Yes*, did this contribute to any of the following (circle any that apply)?

Course Credit Work Experience

Course Requirement Certificate (such as ANU+)

C3/ Are you responsible for the regular care of a family member? Yes No

Engineering Beliefts

B1/ Use the scale of 1 (NI - not important), 2 (N -neutral), 3 (I - important) to 4 (VI - very important) to rate how important you think each of the following areas are for a professional engineer.

Area	NI	N	I	VI
Fundamental knowledge (such as maths and science)	1	2	3	4
Business skills (project management, entrepreneurship)	1	2	3	4
Research skills (conducting research, contemporary issues)	1	2	3	4
Interdisciplinary knowledge (from a non-engineering field or discipline)	1	2	3	4
Engineering Discipline knowledge (in my major area)	1	2	3	4
Professional skills (such as communication or teamwork)	1	2	3	4
Ethical practice (integrity, social responsibility, sustainable development)	1	2	3	4
Technical skills (design process, simulation, modelling, …)	1	2	3	4
Systems engineering (defining scope and problem, systems boundaries, considering lifecycles)	1	2	3	4

B2/ The following statements relate to your views of engineering and engineers. Please rate on a scale of 1 (strongly disagree) to 5 (strongly agree) your agreement with the following statements.

Statement	SD	D	N	A	SA
Engineers should use their skills to solve social problems	1	2	3	4	5
The engineering profession needs to be more diverse	1	2	3	4	5
it is important to me personally to have a career that involves helping people	1	2	3	4	5
In general, being an engineer is an important part of my self-image	1	2	3	4	5
I will actively use engineering to help others	1	2	3	4	5
Engineering and technology alone can solve social problems	1	2	3	4	5
Engineering can have a negative impact on society	1	2	3	4	5
It is not my responsibility to do something about improving society	1	2	3	4	5
I will be happy to be an engineer	1	2	3	4	5
Overall, being an engineer has very little to do with how I feel about myself	1	2	3	4	5
I often regret that I chose to be an engineer	1	2	3	4	5
Being an engineer is important to how I feel about myself	1	2	3	4	5
I identify with engineers	1	2	3	4	5
It is the role of engineers to contribute to improving society	1	2	3	4	5

B4/ Please rate on a scale of 1 (strongly disagree) to 5 (strongly agree) your agreement with the following statements in relation to your engineering classes

In my engineering classes I feel	**SD**	**D**	**N**	**A**	**SA**
Frustrated	1	2	3	4	5
Angry	1	2	3	4	5
Overworked	1	2	3	4	5
Happy	1	2	3	4	5
Enthusiastic	1	2	3	4	5
Insecure	1	2	3	4	5
Fulfilled	1	2	3	4	5
Challenged	1	2	3	4	5
Motivated	1	2	3	4	5

Motivations:

M4/ From the application areas below, rate on a scale of 1 (no interest) to 4 (strong interest) which areas are you potentially interested in applying your engineering with when you graduate?

Application Area	**No Interest**	**Some Interest**	**Interested**	**Strong Interest**
Multi-national corporations	1	2	3	4
Entrepreneurship (start-up companies) or own business	1	2	3	4
Government or public policy	1	2	3	4
Competitive sports	1	2	3	4
Humanitarian responses, or community, not-for-profit or social organisations	1	2	3	4
Research and development (R&D)	1	2	3	4
Defence / Defence Industry	1	2	3	4
Engineering manufacturers or industrial organisations	1	2	3	4
Consultancies	1	2	3	4
Education or training	1	2	3	4
Technology or project management	1	2	3	4

M1/ A definition of Humanitarian Engineering is that it…

"brings enhanced well-being, welfare, and comfort to any individual or community in disadvantaged circumstances and is inclusive of research, design, manufacturing and construction. The issues to be addressed in engineering terms might include chronic ongoing conditions for an individual or group, or be associated with high-impact disasters and emergencies which imperil large numbers of people".

With this definition in mind please circle your level of agreement with the following statement.

My research project is Humanitarian Engineering	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

M2/ Please select and circle exactly five statements from the list below that you feel most reflect your motivations for choosing your research topic. Please read all of the statements before you make your selection. You do not need to rank your selections**.**

Was inspired by my personal experiences

Was looking for a truly challenging task

Was Interested in new and emerging technologies

To try something new

To learn or develop professional skills

To put what I know into practice

To collaborate with like-minded people

To experience real world issues first hand

To gain experience relevant to my intended career

To make a contribution to society

To understand how engineering is used in the real world

To create positive social impact

To work on the same or similar topic to a friend

To learn or develop technical skills

My friends encouraged me to select this topic

To earn course credits towards my degree

To engage more deeply in a topic I had an existing connection to

To build up my CV

My parents or a family member encouraged me to select this topic

To make new connections that might help my career

To work directly with and help people who might be disadvantaged

My supervisor or an academic at my university encouraged me to select this topic

If you were motivated by something that is significantly different form the statements above please

state: ____

Demographics

D1/ Are you receiving a scholarship for your degree? Yes No

D2/ For enrolment are you a (circle one): Domestic student International student On Exchange

D3/ How would you characterise your average course marks (circle one)?

upper HD HD D CR P Other (please state): _______

D4/ What is your age? ____________

D5/ Please select your gender (circle one):

Female Would prefer not to specify

Male Indeterminate / Intersex / Unspecified

D6/ Is English (circle one): your first language not your first language

D7/ Other than your first language, do you know any other languages? Yes No

D7a/ If *Yes*, what other languages do you know? ____

D7b/ If *No*, have you studied any other languages? Yes No

D8/ Do you have a close family member who is or has been an engineer? Yes No

D10/ Are you the first generation of your family to attend university? Yes No

D12/ Where did you spend most of your time growing up? Rural Area Urban Centre

D13/ For your enrolment, are you studying (circle one)? Full Time Part Time

D14/ Did you identify as Aboriginal or Torres Strait Islander? Yes No

D15/ What has been you most common living arrangement while studying (circle one)?

Residence / Hall Shared Off-campus With family

D16/ During your studies have you been supported by ANU's Access and Inclusion Hub?

Yes No

Humanitarian Engineering Background

The following questions relate specifically to *Humanitarian Engineering*

E1/ What is your understanding or definition of *humanitarian engineering*?

E4/ For each of the following activities and experiences, circle all those you have completed. For those you have completed rate on a scale of 1 (no motivation) to 4 (strong motivator) how each contributed to your motivation for undertaking your humanitarian engineering research project?

Activity / Experience	**Completed**	**No Motivation**	**Some Motivation**	**Motivator**	**Strong Motivator**
EWB Challenge	Y	1	2	3	4
Engineering for a Humanitarian Context Course	Y	1	2	3	4
EWB Design Summit	Y	1	2	3	4
Enabled Futures Study Tour (Singapore)	Y	1	2	3	4
Accessibility Project	Y	1	2	3	4
Healthcare Project	Y	1	2	3	4
Social Enterprise / Innovation Project	Y	1	2	3	4
R&D Project (BE R&D) on a humanitarian engineering topic	Y	1	2	3	4
EWB Outreach	Y	1	2	3	4
EWB Chapter Member or Volunteer	Y	1	2	3	4
Volunteer or Community Work	Y	1	2	3	4
Work experience or internship	Y	1	2	3	4

E4a/ If other activities or experiences please state:

____

4b/ CECS Research: Post Survey

Unless otherwise stated questions mentioning your *experience* are referring to your just completed research project.

Study:

S1/ What degree program are you enrolled in? ____

S2/ What major(s) are you currently,

or most likely to consider, studying? ____

S3/ What minor(s) are you currently,

or most likely to consider, studying? ____

S4/ What year are you? _________________________

S5/ What age were you when you started your current studies? _____________________

S6/ Did you have a gap year between finishing school and starting university? Yes No

S8/ What research experience have you just completed (circle one)?

ENGN4200 ENGN4712 ENGN2706 ENGN2707 ENGN3712 ENGN4221

Other (please state): ____

S9/ Did your project have an external partner to collaborate with or who provided your topic?

Yes No

S9a/ If *Yes*, who was the external partner? ____

S9b/ If *Yes*, what benefits, outcomes or impact do you think you have created, if any, for the partner organisation involved in your experience? If no benefits, outcomes or impact, why not?

O5/ Rate the learning gains you made from this experience in the areas below from 1 (no gain) to 4 (significant gain):

Learning Gain	**None**	**Minor**	**Some**	**Significant**
Application of engineering to the real-world	1	2	3	4
Communication skills	1	2	3	4
Adaptability	1	2	3	4
Creativity	1	2	3	4
Research skills	1	2	3	4
Cross-cultural awareness	1	2	3	4
Teamwork skills	1	2	3	4
To my discipline major	1	2	3	4
To the systems engineering core	1	2	3	4
Ethical practice	1	2	3	4
Incorporating sustainability into engineering	1	2	3	4
Engineering design	1	2	3	4
Engaging with users or stakeholders	1	2	3	4
Ability to work internationally	1	2	3	4
Ability to work on complex problems	1	2	3	4
Ability to incorporate social factors into engineering	1	2	3	4

O6/ Has this experience contributed to your employment preferences? Are you more likely to seek employment in:

Application Area	**Less Likely**	**A Little Less**	**The Same**	**A Little More**	**More Likely**
Multi-national corporations	1	2	3	4	5
Entrepreneurship (start-up companies) or own business	1	2	3	4	5
Government or public policy	1	2	3	4	5
Competitive sports	1	2	3	4	5
Humanitarian responses, or community, not-for-profit or social organisations	1	2	3	4	5
Research and development (R&D)	1	2	3	4	5
Defence / Defence Industry	1	2	3	4	5
Engineering manufacturers or industrial organisations	1	2	3	4	5
Consultancies	1	2	3	4	5
Education or training	1	2	3	4	5
Technology or project management	1	2	3	4	5

O7/ For your experience please rate the following statements on a scale of 1 (strongly disagree) to 5 (strongly agree):

Statement	SD	D	N	A	SA
I learnt new engineering skills and knowledge	1	2	3	4	5
I used or applied my engineering skills and knowledge	1	2	3	4	5
This was relevant for my current studies	1	2	3	4	5
I learnt about my role as an engineer	1	2	3	4	5
I gained global competencies or knowledge	1	2	3	4	5
I am more likely to find employment	1	2	3	4	5
I am more motivated to complete my studies	1	2	3	4	5
I am more motivated to be an engineer	1	2	3	4	5
I can better connect my studies to the application of engineering knowledge	1	2	3	4	5
I made new friends	1	2	3	4	5
I had a sense of individual achievement	1	2	3	4	5
I can better connect engineering theory to practice	1	2	3	4	5

O4/ What impact do you think this experience had on your future engineering practice (circle one)?

1. very negative impact (ie not sure if I want to continue with engineering study)
2. negative impact (ie waste of time and should have done something else)
3. somewhat negative impact
4. no or little impact
5. somewhat positive impact
6. positive impact
7. very positive impact (changed my future study and/or career plans)

Humanitarian Engineering Outcomes:

E2/ Were you involved with any study abroad programs (such as field schools, study tours or exchanges) or field work related to your project? This could be before or during your project, as background, for data collection, or that provided specific motivation.

Yes No

E2a/ If *Yes*, which study abroad experience(s) did you complete related to your project?

International Experience	Duration (weeks)	When (Year)
Field Work (state location): ____________________________	_______	____________
EWB Summit (state location): __________________________	_______	____________
IARU Course (state location): __________________________	_______	____________
Exchange (state university): ___________________________	_______	____________
Other (please state): _________________________________	_______	____________

E2b/ If *Yes*, what impact, if any, did the study abroad or fieldwork have on your experience?

Demographics

D1/ Are you receiving a scholarship for your degree? Yes No

D2/ For enrolment are you a (circle one): Domestic student International student

D3/ How would you characterise your average course marks (circle one)?

upper HD HD D CR P Other (please state): _______

D4/ What is your age? ____________

D5/ Please select your gender (circle one):

Female Would prefer not to specify

Male non-Binary Other

D6/ Is English (circle one): your first language not your first language

D7/ Other than your first language, do you know any other languages? Yes No

D7a/ If *Yes*, what other languages do you know? ____

D7b/ If *No*, have you studied any other languages? Yes No

D8/ Do you have a close family member who is or has been an engineer? Yes No

D9/ Do you have a close family member who is or has been involved with humanitarian work?

Yes No

D10/ Are you the first generation of your family to attend university? Yes No

D12/ Where did you spend most of your time growing up? Rural Area Urban Centre

D13/ For your enrolment, are you studying (circle one)? Full Time Part Time

D14/ Did you identify as Aboriginal or Torres Strait Islander? Yes No

D15/ What has been you most common living arrangement while studying (circle one)?

Residence / Hall Off-campus (shared or own) With family

D16/ During your studies have you been supported by ANU's Access and Inclusion Hub?

		Yes	No
D17/ If you have or are finishing your studies, are you in, or about to enter, employment?			
	Not Finishing	Yes	No
D17a/ If *Yes*, is this a full-time position?		Yes	No

5a/ Interview Script Question Prompts

1/ What study program did you, or are you about to, complete? Why did you study engineering or become an engineer? What were some of your motivations?

2/ What was your first exposure to humanitarian engineering? Was it outreach, EWB Challenge, a media/news article, a friend, parent, teacher, …? Was this before or after you started you degree?

3/ Describe your humanitarian engineering experience at ANU. What humanitarian engineering experiences have you had? What humanitarian engineering education initiatives have you involved with while studying? Were you involved with any outside activities? What project topics or assignments did you undertake?

4/ What were your initial motivations or reasons for engagement with humanitarian engineering? What factors lead to you undertaking these initiatives or experiences? Were there any external factors that encouraged or influenced you?

5/ Did these the same motivations or factors change over time?

6/ What engineering skills or knowledge do you think you have developed or gained from your humanitarian engineering experiences? Did humanitarian engineering education, initiatives or experiences give you skills, knowledge, experience or learning that you did not get in other parts of your studies? What were some of these?

7/ What impact, if any, did your humanitarian engineering education have on your overall time as a student? Did humanitarian engineering education provide motivations for your studies more broadly? Were there any other outcomes?

8/ How well could you integrate or relate your humanitarian engineering education experiences with your studies? Were they complementary or overlapping or supporting each other? How was the flow or your 'program'?

8a/ What impact do you think your humanitarian engineering experiences had outside your studies, with partners? Did you provide any outcomes to external groups?

10/ How applicable are the skills or knowledge you gained to your current or future work or engineering work in <u>Australia</u>? How, are you or could you apply these skills or knowledge? In what areas or contexts?

11/ During any interviews or gaining employment after graduation, do you think any of your humanitarian engineering experiences were of interest or particularly relevant? Did you employers / interviewers so interest in any? Do you think your humanitarian engineering education contributed to your employment or prospects?

12/ Do you think you will stay in engineering or your current employment?

13/ Do you want to work in humanitarian assistance or development now or in the future? What do you feel prepared for?

14/ Was there anything you particularly enjoyed about humanitarian engineering? How did you find the culture around your HE studies particularly compared to the rest of your studies?

15/ Did you have any frustrating experiences from studying humanitarian engineering? Anything lacking or gaps? Were there any barriers to your humanitarian engineering education experiences or undertaking further experiences? Would you like to have had more or less or different humanitarian engineering education experiences?

16/ What do you consider humanitarian engineering? Is it all engineering? Do you think humanitarian engineering is an appropriate or meaningful name? Did you think humanitarian engineering is important, and if so why?

17/ Do engineers have a role to play in humanitarian work? What role does technology have to play in humanitarian work? Should all engineers have some education in humanitarian engineering?

18/ Do engineers have a role in improving society or overcoming social problems? Do you think technology has a role to play in improving society? If so, what role? Do engineers have a responsibility for the outcomes of their engineering work or technology they create? What form may that responsibility take?

9/ Do you think you should have had some 'recognition' for your humanitarian engineering studies? A certificate, a qualification, …?

5b/ Interview Demographic Survey

D1/ When did you complete your most recent studies?

D2/ For enrolment are you a (circle one): Domestic student International student

D3/ What is your age? ____________

D4/ Please select your gender (circle one):

Female Would prefer not to specify

Male Indeterminate / Intersex / Unspecified

D5/ Is English (circle one): your first language not your first language

D6/ Do you have a close family member who is or has been an engineer? Yes No

D7/ Do you have a close family member who is or has been involved with humanitarian work?

Yes No

D8/ Are you the first generation of your family to attend university? Yes No

D9/ Where did you spend most of your time growing up? Rural Area Urban Centre

D10/ Did you identify as Aboriginal or Torres Strait Islander? Yes No

D11/ During your studies have you been supported by ANU's Access and Inclusion Hub?

Yes No

D12/ If you have or are finishing your studies, are you in, or about to enter, employment?

Not Finishing Yes No

D12a/ If *Yes*, is this a full-time position? Yes No

Appendix III: Humanitarian Engineering - What Does it all Mean?

Introduction

This Appendix contains a conference paper exploring the understanding of the term Humanitarian Engineering in Australia and New Zealand. It includes an overview of previous research and describes the terms used internationally and provides results from a voluntary survey of practitioners and academics completed in Australasia.

Humanitarian Engineering - What does it all mean?

Jenny Turner[a], Nick Brown[a] and Jeremy Smith[b]
Engineers Without Borders Australia[a] and Australian National University[b]

Structured Abstract

BACKGROUND OR CONTEXT

Humanitarian Engineering is a term that has become wide spread in the last 15 years with the growth of organisations such as Engineers Without Borders and educational opportunities and initiatives in the development world. However, the term has different meanings and understandings related to types of humanitarian work undertaken and national approaches. Numerous definitions have been provided including Miller (2008), Muñoz and Skokan (2007), VanderSteen (2008) and White (2011). Hill and Miles (2012) explored student understanding of the term at one institution in the UK and concluded understandings vary and further exploration of the term is required within individual education providers to develop their educational initiatives. In Australia one definition was provided by Engineers Australia in 2011 as part of the Year of Humanitarian Engineering (in Greet 2014) but there has been little discussion or critique of this.

PURPOSE OR GOAL

This work sought to generate an understanding of the term Humanitarian Engineering in Australia. This was to allow for a common language as a starting point to support further development of the field and its study in Australia.

APPROACH

Initial research was conducted into definitions of humanitarian engineering in Australia and other countries for any common understanding or language. A range of definitions were identified which covered aspects of the humanitarian spectrum, from disaster relief to community development, as well as the role of the engineer and engineering practice. Based on these initial findings a survey was developed with a number of questions allowing for a range of understandings to be selected. This covered the geographical location and context for humanitarian engineering as well as the role of the engineer. Responses were collected from engineering and development practitioners and students with a range of experiences in Australia.

DISCUSSION

As found with other research, a range of understandings were generated from the survey. However, the understanding in Australia generally covers a wider range of humanitarian responses and contexts than definitions from other countries. This suggests that humanitarian engineers in Australia operate in a wider range of contexts than comparable countries overseas.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

A survey was conducted to explore the understanding of the term Humanitarian Engineering in Australia. Results from this will help practitioner organisations and education providers to further develop the field in Australia providing a level of shared understanding.

Full Paper

Background

Over the past eight years the number of initiatives within Australia focused on humanitarian engineering has grown. This has given rise to the need to develop a common understanding of the term humanitarian engineering within Australia as a basis for alignment and agreement on core competencies, skills and knowledge required to practice humanitarian engineering. Humanitarian engineering (HE) as a term has become widespread since the turn of the century. This has been driven by the rise of HE organisations, often not-for-profits, university education initiatives and academic publications. For example, numerous independent Engineers Without Borders (EWB) organisations have started since 2000 including EWB Canada (founded in 2000), EWB UK (2001), EWB USA (2002), EWB Australia (2003), EWB New Zealand (2008) and EWB-Asia (2014). HE education programs, centres or initiatives are established at universities including Coventry University in the UK (Hill and Miles, 2012) and Ohio State University (Passino, 2009), Pennsylvania State University (Dzombak and Mehta, 2013) and Colorado School of Mines (Leyden and Lucena, 2014) in the USA.

However within these organisations and initiatives a number of different meanings and understandings of HE exist. Passino (2009) highlights the role of technology development and voluntary service for humanitarian engineers, as either graduates or students. Campbell and Wilson (2011) provide a definition as “the application of engineering skills or services for humanitarian aid purposes, such as disaster recovery or international development” while Dzombak and Mehta (2013) emphasise “efforts to improve the wellbeing of marginalized communities with technology-based solutions”. These broadly consider HE as the application of engineering, in terms of technology development and associated processes and services, for humanitarian interventions. Within these programs interventions typically focus on international development and disaster response, reflecting the increase in global engineering and opportunities in USA engineering programs (such as Zoltowski and Oakes, 2014).

Under this definition other programs not labeled humanitarian engineering could also be considered. For example, the Engineering for Developing Communities centre at the University of Colorado Boulder has a focus on applying engineering for international (non-USA) developing countries (Amadei and Wallace, 2009). Development Engineering itself has been highlighted as a new field with a focus on technology interventions and design with an emphasis on complex, low resource, poor settings (Nilsson et al, 2014).

In the UK, HE has emerged from a more traditional understanding of humanitarian work as disaster response. However with the establishment and growth of organisations such as EWB-UK and programs including that at Coventry University a broader understanding is emerging. In data collected at Coventry University on students’ understandings of HE, Hill and Miles (2012) found the most important issues addressed by HE were “solving social problems” and “sustainability in developing countries”, with “poverty reduction” seen as less important. This highlights the view among students that HE is still commonly done ‘internationally’ rather than within one’s own country.

A different understanding of HE has emerged emphasising the impacts and consequences of engineering and technology for a community or individual, and the role they play rather than a focus on technology development. This seeks to address the disadvantage a community or individual faces, and seeks to achieve social justice outcomes. Leydens and Lucena (2014) provide a definition of social justice in relation to engineering as “engineering practices that strive to enhance human capabilities through an equitable distribution of opportunities and resources while reducing imposed risks and harms among agentic citizens of a specific community”. This focuses more on the outcomes seeking to be achieved rather than only the development of technology. However, as highlighted definitions of social justice are also dynamic and contested. Other works have sought to examine the context or location where

HE can occur. In contrast to many of the global or international HE initiatives in the USA, VanderSteen et al (2009) explores the benefits and ethics of such programs and highlights the role of HE in one's own community or location, particularly for engineering students.

In Australia the term HE was seldom used prior to 2011. For example, the 2010 strategy for EWB-Australia makes no mention of HE but instead refers to 'development engineering', while the organisations mission developed within two years of the strategy refers to 'humanitarian engineering' (EWB, 2015). The term emerged in 2011 with Engineers Australia's Year of Humanitarian Engineering (YoHE). This provided a definition for HE within Australia as "brings enhanced well-being, welfare, and comfort to any individual or community in disadvantaged circumstances and is inclusive of research, design, manufacturing and construction. The issues to be addressed in engineering terms might include chronic ongoing conditions for an individual or group, or be associated with high-impact disasters and emergencies which imperil large numbers of people." (in Greet, 2014). This highlights disadvantage as the key condition to be addressed and covers a range of contexts from long-term community development to disaster response. Greet (2014) takes this further highlighting HE as "a social concept which encourages improved employment and engagement of engineering resources, delivering humanitarian outcomes."

Understandings of HE were also explored in the documentary by Sheena Ong (Ong, 2014). This interviewed humanitarian engineers in Australia, considering that to encompass working domestically and international and in disaster response to community development. It proposed a number of definitions most of which are seeking to address disadvantage.

In all of these discussions HE is understood to be a complementary or parallel application of other disciplines of engineering. As a minimum it focuses strongly on understanding the context where engineering will take place and an additional skill set for engineering practice. These additional skills are often drawn from the social sciences, particularly development studies (Leydens and Lucena, 2014; and Nilsson et al, 2014), and business specifically social enterprises (Hill and Miles, 2012; and Dzombak and Mehta, 2014).

This paper aims to conduct research into the understanding of the term humanitarian engineering and to provide recommendations about how to achieve a consistent understanding of the term within Australia. This work will provide a basis for further discussions on alignment of competencies and learning outcomes in addition to informing new curriculum development in this field within Australia.

Humanitarian Engineering Education Initiatives

Although humanitarian, or development, engineering has not been embedded into engineering curriculum in the same way that sustainability has been, there are a number of standalone programs dedicated to its education. The most established tend to be found in the USA; examples include Humanitarian Engineering at the Colorado School of Mines, which is entering its second decade, and the Engineering for Developing Communities program which started in 2003 at the University of Colorado Boulder. Both of these offer specific programs including a mix of course-work and service-learning opportunities. The EPICS program (Engineering Projects in Community Service), which started at Purdue University in 2003 but has expanded to other institutions, also provides service-learning opportunities to engineering students (Coyle et al, 2005). Two HE courses offered by the Humanitarian Engineering Centre at Ohio State University (U.S.A) prepare students, through the teaching of the theory, to be professional humanitarian engineers (Passino, 2009). To complete a minor in humanitarian engineering students are additionally required to take part in service-learning programs, locally or internationally. In the UK, Master of Science programs are available including Humanitarian Engineering and Computing at Coventry University, and Engineering for International Development at University College London. Other universities, notably Manchester University and Cambridge University, have courses focusing on International Disaster Management and sustainable development respectively, which contain aspects of humanitarian engineering.

Within Australia, many of the recent humanitarian engineering education (HEE) initiatives have been developed or supported by Engineers Without Borders Australia (EWB). The EWB Challenge aims to introduce concepts of HE to students. Delivered in partnership with EWB UK and EWB NZ, the EWB Challenge currently has a global reach of over 10,000 students through first year courses at 58 universities. Final year undergraduate students at Australian universities are able to take part in EWB's Humanitarian Engineering Research Program, established in 2009. Research projects are generated by community development organisations to support their work. In early 2015 EWB established its Humanitarian Design Summit program that enables undergraduate students to take part in an immersive cultural and participatory design experience based in Cambodia and led by experienced facilitators and academics.

In addition to the programs offered by EWB there are a number of related, dedicated courses at universities around Australia. The University of Western Australia (UWA) offers two courses (as outlined in Baillie and Armstrong, 2013) related to engineering for social and environmental justice, Global Challenges in Engineering (a compulsory first-year) and Critical Theories of Technological Development (an elective unit). At the University of Wollongong (UoW) a current OLT project on Integrating Indigenous Student Support through Indigenous Perspective Embedded in Engineering Curricula is leading towards a course in Indigenous Engineering (Goldfinch et al, 2014). The School of Health at Charles Darwin University runs a Master of Emergency and Disaster Management, which focuses on the management side of humanitarian work.

Approach

Based on the range of definitions identified from literature, a survey was developed to gain an understanding of the term *Humanitarian Engineering* in Australia. This focused on three key areas:

1. the areas HE's may have a role to play in;
2. the contexts HE's may have a role to play in; and
3. the activities HE's may have a role to play in for the areas and contexts identified.

The areas, contexts and activities listed in the survey questions were compiled from existing definitions of humanitarian engineering in the literature. This allowed participants to highlight any of the existing definitions along with combinations of those. Engineering and humanitarian background was surveyed along with basic demographic information. The ethical aspects of this research were approved by the Australian National University (ANU) Human Research Ethics Committee. The survey was disseminated through engineering education and professional networks.

At the time of writing the survey had been completed by 119 participants. Of the survey participants 80% had an engineering background, 55% were students studying for an engineering degree, 40% had completed the EWB Challenge at university and 26% had watched Ong's documentary. While the majority of the survey participants identified as having an engineering background only 45% had been involved with what they considered humanitarian work or assistance (paid or voluntary).

As highlighted in Figure 1, the majority of survey respondents considered HE to have a role to play in all the areas listed. However of these areas "economic development or wealth creation" and "addressing systematic inequality" stand out with 47% and 45% respectively of respondents considering HE to play a minor role only. The majority of survey respondents considered HE to have a role to play in all contexts with "developing countries" and "rural and remote locations" standing out with over 94% and 88% respectively of respondents considering HE to play a major role. In contrast "urban environments" stands out as a context where HE plays the least role with 47% of respondents considering HE to only play a minor role. For the areas and contexts selected the majority of survey respondents considered HE to have a role to play in all activities listed. Standing out as activities were "applying engineering", "design under social and environmental constraints" and "'problem-solving" with over 90% of respondents considering HE to have a role to play for all three activities. This is probably not surprising considering that these activities overlap most with a traditional definition of engineering. In contrast the activities where HE was considered to have the least role to play were "provide compassion and care" and "promote and seek social justice" with 53% and 45% of respondents considering HE to only have a minor role to play respectively.

A	Poverty alleviation	H	Economic development or wealth creation
B	Disaster or emergency response	I	Addressing systematic inequity
C	Solving complex social problems	J	Working with marginalised, under-served or vulnerable
D	Global (cross-national boundaries) engineering work	K	Solving endemic global problems
E	Sustainable community development	L	Infrastructure development
F	Improving circumstances of injustice or inequity	M	Meeting basic (physiological) needs of all
G	Disaster preparedness	N	Education, training or capacity building

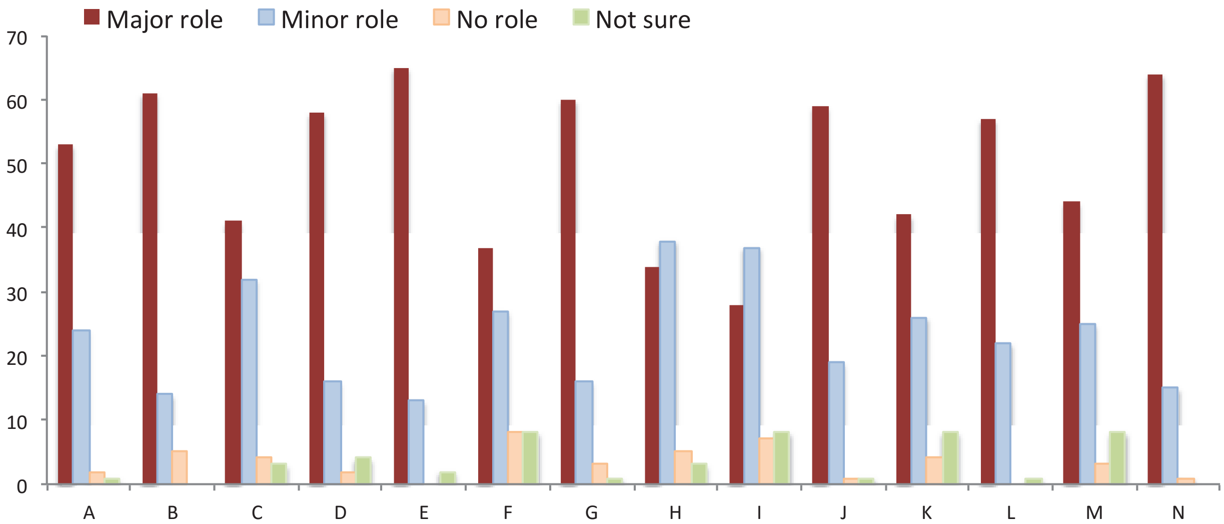


Figure 1 – Results of the understanding of the term humanitarian engineering survey showing what *areas* humanitarian engineers have a role to play in

When asked if HE was a specific engineering discipline, such as chemical or mechanical engineering, or a subset to a specific engineering discipline 50% considered HE to be a subset of an engineering discipline and only 10% considered it to be a specific discipline unto itself. Of the 40% who selected other as a response the written responses include terms like "A values orientation that should underpin all types of engineering", "Each engineering discipline can be used in a humanitarian way", "Applying engineering solutions with a major consideration for the social impacts" and "'Supplementary' makes it sound like a cheap add on. But I think that it is not a discipline in itself (like Mechanical) but is definitely its own area of expertise. In a lot of ways, ALL engineering work should be undertaken with a touch of 'humanitarian engineering' in mind".

A	Developing countries	E	Overseas disaster impacted area
B	Remote or rural locations	F	Within their local community
C	Urban environments	G	Overseas disaster prone area
D	Local disaster impacted area	H	Local disaster prone area

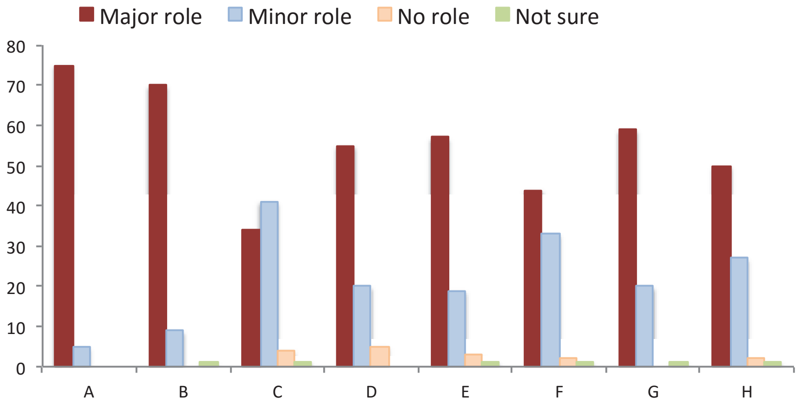


Figure 2 - Results of the understanding of the term humanitarian engineering survey showing what *contexts* or *locations* humanitarian engineers work in

A	Apply engineering (research, design, manufacturing, construction, …)	J	Conduct ethical practice
B	Provide compassion and care	K	Work to reduce imposed risks and harms
C	Design under social and environmental constraints	L	Promote enhanced or improved well-being, welfare and comfort
D	Engage and use natural and human resources	M	Promote human social and cultural development
E	Create improved employment opportunities or capabilities	N	Create technologies that help people
F	Implement long-term sustainable solutions	O	Promote equitable distribution of opportunities and resources
G	Empower individuals and communities to develop technological solutions	P	Problem-solve
H	Promote and seek social justice	Q	Promote stakeholder and end-user interaction, collaboration and engagement
I	Contribute to a culture of peace and a just existence		

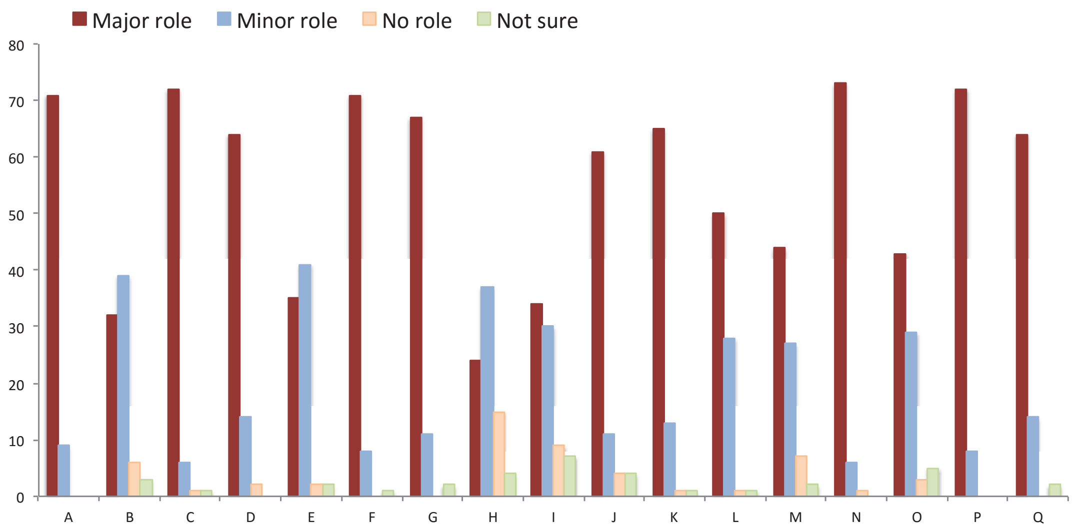


Figure 3 - Results of the understanding of the term humanitarian engineering survey showing the *activities* that humanitarian engineers conduct

Discussions

The results of the survey highlight the broader understanding of HE in Australia compared to other countries examined here. It appears to be generally understood to be engineers developing technology in rural, remote or developing communities for disaster relief or long-term development. Examining the range of understandings for areas where humanitarian engineers may have a role to play, HE was seen as having a major role for those related to disasters, technology development and community development. When considering the contexts or locations, HE was seen to have a major role in any disaster impacted or prone area as well as developing countries and remote or rural locations. The role was seen as less for urban environments or within the respondents' own community. This indicates less of a divide between international and domestic work as seen in many USA programs for example and reflects the views in the definitions developed for the YoHE and Ong (2014). This understanding should be incorporated into any HE course development, to ensure elements of both domestic and international assistance are including along with disaster response and community development while highlighting the need to incorporate to local, particularly urban, HE work.

Examining the results for the activities humanitarian engineers understood to be involved with, those related to social justice, peace and compassion were seen to have the least roles. The major roles were still identified as those most closely aligned with a view of engineering broadly around technology development and design under constraints. This highlights the need to ensure social justice elements are incorporating into HEE initiatives, as in the work of Baillie and Armstrong (2013) and Leydens and Lucena (2014). It should be noted the understanding and definitions of HE was limited to English-speaking developed countries. There is little description of HE seen in other countries, particularly developing countries where much of the HE efforts are focused. This should be explored further to gain an understanding of how HE is viewed from potential partners in developing countries.

Conclusion and Recommendations

This paper has documented the understanding of the term Humanitarian Engineering in Australia and has described the current state of Humanitarian Engineering Education in the domestic university sector. A number of recommendations have come from this research, some of which require the collaboration of interested universities in Australia. These recommendations relate to the sharing of curriculum resources between institutions, the sharing of initiatives between institutions and importantly the development of a framework for the requirements of formal HE qualifications. Specific recommendations are:

Recognition of HEE initiatives: A framework for recognising and assessing HEE offerings for any formal qualifications or recognition needs to be established. This should engage relevant organisations working in humanitarian engineering in Australia to establish requirements to which universities can align their offerings.

Sharing of curriculum resources: An open and mutually beneficial platform needs to be developed to promote sharing of material and resources across institutions.

Sharing of HEE initiatives: Courses are being developed at institutions based upon their strengths and expertise, such as engineering and social justice at the University of Western Australia and Indigenous engineering at the University of Wollongong. With HEE an emerging field many educators have little field experience and most no formal qualifications. Rather than replicating courses at institutions with a lack of expertise the opportunity exists to share HEE initiatives through cross-institutional study or a joint-programs.

In addition to the three recommendations above that specifically require collaboration there are two further recommendations:

Knowledge development for educators: support for development and training should be provided for interested educators. This could include field experience, which few educators have, and potentially a qualification. The new EWB Humanitarian Design Summit provides an opportunity for short term experience but other opportunities should be investigated.

Evaluation of HEE initiatives: Both the effectiveness and outcomes achieved through HEE initiatives need to be further explored and evaluated, in particular, students engaging with multiple initiatives across their degree programs, both for credit and extra-curricular activities.

References

Amadei, B., and Wallace, W. A. (2009). Engineering for humanitarian development. *IEEE Technology and Society Magazine*, *28*(4), 6–15.

Campbell, R. C., and Wilson, D. (2011). *The Unique Value of Humanitarian Engineering*, AC 2011-2701, American Society for Engineering Education.

Dzombak, R., & Mehta, K. (2014). Scholarly Advances in Humanitarian Engineering and Social Entrepreneurship: A Typology of Research Publications. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, 98–116.

EWB (2015) http://www.ewb.org.au/about/ourstrategy last accessed August 19, 2015.

Goldfinch, T., Ilango, A., Roland, A., and Willis, J. (2014). *Australian Indigenous Culture and Heritage in Engineering Project Planning and the Implications for Engineering Education*. Proceedings of the Australasian Association for Engineering Education Annual Conference, Wellington, NZ.

Hill, S., and Miles, E. (2012). *What do Students understand by the term 'Humanitarian Engineering'?* Innovation, Practice and Research in Engineering Education, September 2012.

Leydens, J. A., and Lucena, J. C. (2014). Social Justice: A Missing, Unelaborated Dimension in Humanitarian Engineering and Learning Through Service. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, *9*(2).

Nilsson, L., Madon, T., and Sastry, S. S. (2014). Toward a New Field of Development Engineering: Linking Technology Design to the Demands of the Poor. *Procedia Engineering*, *78*, 3–9.

Ong, S. (2014). *The Humanitarian Engineering.*

Passino, K. M. (2009). Educating the Humanitarian Engineer. *Science and Engineering Ethics*, *15*(4), 577–600.

VanderSteen, J., Baillie, C., and Hall, K., 2009. International Humanitarian Engineering - Who Benefits and Who Pays? *IEEE Technology and Society Magazine*, Winter 2009.

Zoltowski, C. B., & Oakes, W. C. (2014). Learning by Doing: Reflections of the EPICS Program. International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship, 1–32.

Acknowledgements

Support for this project has been provided by the Australian Government Office for Learning and Teaching. The views in this project do not necessarily reflect the views of the Australian Government Office for Learning and Teaching.

Copyright

Appendix IV: The Design and Installation of Solar Home Systems in Rural Cambodia

Introduction

This Appendix is the first in a trilogy of papers describing research undertaken by students engaged in the Humanitarian Engineering pathway at the ANU. The papers' lead author was a final year engineering student, Rebecca Watts, and the paper focuses on her research on solar home systems in rural Cambodia. This research was undertaken during her involvement in two EWB Summits to Cambodia, the first as a student (participating in the first ever EWB Summit) and the second as a mentor, as well as her final year individual research project. For her research thesis, Ms Watts was awarded the Regional Winner (Oceania) in the engineering discipline category in the 2016 Global Undergraduate Research Awards. She was the first student to undertake all the elements of the HumEng pathway at the ANU when it was completed in 2015. This first publication is a conference paper for a solar energy research conference.

Rebecca Watts

The Design and Installation of Solar Home Systems in rural Cambodia

Rebecca Watts[1], Andrew Thomson[2], Jeremy Smith[2] and Koky Saly[3]

[1]*Centre for Sustainable Energy Systems, ANU, Canberra Australia*

E-mail: Rebecca_watts@live.com

Abstract

Clean and affordable energy development in rural communities in Cambodia plays an important role environmental sustainability and in economic development. Due to the lack of existing infrastructure, prevalence of battery powered appliances, and remoteness of many communities; off-grid energy solutions have large potential. The price of electricity in Cambodia is the highest in the region and with the cost of solar panels decreasing, solar energy is a prime candidate in addressing this. Therefore, standalone solar home systems (SHS) are an appropriate product to supply electricity to rural households in Cambodia. This study was conducted as a pilot project to test the appropriateness of the technology and explore the benefits of SHS for households in rural areas. In cooperation with Engineers Without Borders and an in-country NGO, two solar home systems (SHS) were designed, purchased and installed in the Secret Beach community, a rural community in the south of Cambodia. The technology was accepted by the users and generated economic, social and environmental benefits. The community engaged in an education workshop and were involved in the installation of the systems. This facilitated technical knowledge transfer about the functioning of solar energy and operation and maintenance of SHS. This process empowered the community and has generated the desire to expand the systems and roll out similar systems throughout the entire community.

1. Introduction

In Cambodia only 31% of the population have access to electricity and in rural areas, where 80% of the population live, electricity access is as little as 18.8% (World Bank, 2012). Due to the small size of generation, dependence on high cost imported oil and lack of infrastructure, the electricity price is the highest in the region (UN, 2007). Electricity in rural areas is provided by Regional Electricity Enterprises (REEs) which predominately operate on diesel generators, and the tariff ranges between US$0.50-US$1.00/kWh (MIME, 2013).

With the high cost of electricity and in the absence of infrastructure, approximately 50% of the population access alternates energy sources (MIME, 2013). Many rural households have at least one car battery to power lights and appliances. These batteries are charged at small charging stations that depend on high cost imported fuel and incur a cost to the end user of up to US$4.00/kWh, (MIME, 2013). This comes at a significant expense as 40% of the population live near or below the poverty line (World Bank, 2014). Poverty is overwhelmingly concentrated in the rural areas and the poorest quintile has an average daily consumption of US$0.70/day (Asian Development Bank, 2014). The battery charging stations are also detrimental to the environment, producing 153,337 tons of CO_2 annually and are often plagued with poor conditions, posing health threats to users.

Due to the lack of existing infrastructure and remoteness of many communities, off-grid energy has huge potential. Cambodia has high solar irradiance (NASA 2015) and with the cost of solar panels decreasing, solar energy is a prime candidate in addressing the high cost of electricity. Therefore, standalone solar home systems (SHS) have significant potential to provide a long-term, affordable, clean energy solution. Access to electricity helps reduce poverty, increases the living standard and fosters economic development (UN 2007). This report describes the design and implementation process of two SHS in the Secret Beach community, a rural community in the south of Cambodia.

2. Background Information about the Secret Beach Community

The following information details the energy usage and energy sources for households in the Secret beach community. For lighting, households use a combination of lights powered from disposable batteries (US$0.175 per set), kerosene (US$0.875/L) and/or car batteries. To power appliances and charge mobile phones, most households use car batteries. Figure 1 is an image of a car battery in a household in the Secret Beach Community.

Figure 1. Car Battery in Secret Beach Community, (Rebecca Watts)

The car batteries are charged at battery charging stations. As a representation of the survey, Table 1 details the expenditure on recharging and appliances powered by the batteries. The assumed usage (Whrs/day) and calculated levelised cost of electricity (LCOE) are also tabulated.

Table 1

HH	Cost per charge	Frequency of charging	Capability	Assumed usage	LCOE
1	US$0.75	Every week	TV, phone, lights	84Whrs/day	$2.25/kWh
2	2 batteries, US$0.50 each	Every week	Lights, 3 phones	42Whrs/day	$3.62/kWh
3	US$0.80	Every four days	TV, Video player, lights, 2 phones	118Whrs/day	$2.49/kWh

The information in Table 1 outlines the load profile, thus indicating the size and capability requirements for the design of the SHS. The expenditure in the table indicates the financial capacity of the households and the frequency of recharging highlights difficulties in accessing electricity. The time spent taking the battery to the charging station at least once a week reduces productivity. The SHS addresses this as the battery is charged onsite (in the house). therefore, there is a strong case in support of a solar energy.

3. Design and Test

3.1. Aim and Method

To test the operation of the proposed SHS and practice the system set up (to facilitate knowledge transfer when in the community), a model SHS was purchased and tested. This included the following:

Table 2

Component	Description
Solar Panel	InstaPower 100W solar panel with monocrystalline cells
Charge controller	10A, 12V regulator
Car battery	50Ah, 12V, lead acid
Light	55W car headlight (high wattage chosen)
Alligator clips and wiring	12mm wires

The system was assembled to mimic the proposed SHS in the Secret Beach community and placed on the roof on the Engineering building at the Australian National University, illustrated in Figure2.

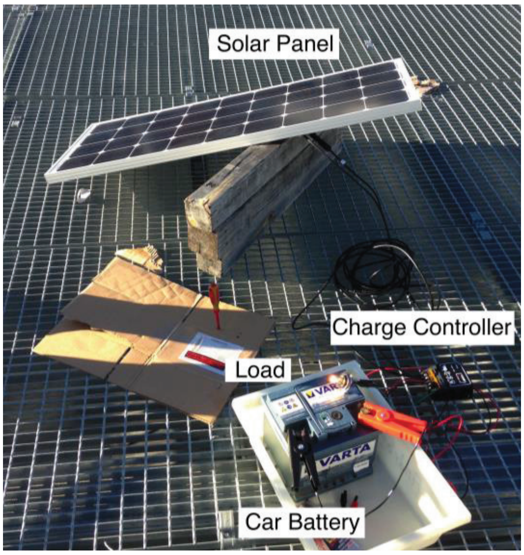


Figure 2. Model System

The tilt angle of the panel was adjusted and the panel was shaded in increments. A load was also added to the system. The sensitivity on output of these variables was tested. The results of the modifications and the implication of this are described in Table 2.

3.2. Results and Discussion

Table 2

Variable	Modification	Result	Implication
Tilt anlge of panel	Panel tilted at different angles.	Optimum tilt approximately 30°. Deviations from this resulted in lower output. The larger the deviation the larger the drop in output.	Panel must be tilted at optimum angle. This is dependent on by location.
Shading of panel	At varying increments, the cells on the module were shaded.	Shading the panel reduced power output.	Panel must be placed in an unshaded area and need to educate the user about the important of maintenance.
Addition of the Load	Panel Shaded: Adding the light bulb.	Adding the light with the panel shaded drew power from the battery.	At night, appliances are powered from battery.
	Panel Unshaded: Adding and removing the light bulb.	Adding the light to the system diverted some (but not all) of the charge.	During the day, low wattage appliances can be used and the battery can be charged simultaenously.

The optimum tilt angle is dependent on location, specifically the latitude due to the elevation of the sun in the sky. For the Australian National University, the optimum tilt angle is approximately 30°. In the Secret Beach community, the optimum tilt angle will be close to 10° due to the proximity to the equator. A lower tilt angle (more horizontal panel) increases the susceptability of the panel collecting dirt. Therefore, there is a trade off between power output and maintenance required. Although not tested, it is important to note the effect of temperature on output. According to the data sheet of the module, the temperature coefficient is -0.47%/°C . The panel should be installed somewhere that has airflow at the back of the panel to prevent overheating and decreases in efficiency.

4. Final Design and Implementation

4.1. Purchased Solar Home System

The following SHS was purchased from a solar energy company in Cambodia.

Table 3

Component	Description
Solar Panel	15W polycrystalline with 8m cable and integrated connector
Battery	7Ah, 12V sealed lead acid
Control unit (excl. battery)	Continuous DC output power: 60W. Battery state of charge display, 2 x USB outputs, 4 x 12V DC outputs
Accessories	2 x 2W LED -128 Lumens USB phone cord with various phone connectors

The SHS has a stored energy of 60Whrs/day, lower than the current usage, (118Whrs/day). The capability is also less as the system powers up to four lights (only two provided) and charges up to two mobile phones. Thus, the SHS is likely to be used in conjunction with the car battery. Thus reducing the use of kerosene and to some extent, the usage of the car battery.

4.2. Workshop with the Secret Beach Community

Prior to the installation of the systems, the community were engaged in workshops about solar energy and the operation and maintenance of the systems, as shown in Figure 3.

Figure 3. Solar Energy Workshops, Cambodia (Rebecca Watts)

4.3. Advantages of Solar Home Systems

The workshop facilitated discussions about the advantages of solar energy. The community members identified current issues in accessing electricity and there was a transfer of knowledge about the features and benefits of the SHS. Through this, the advantages of SHS were acknowledged. This included discussing the increased battery lifetime, reduced reliance on expensive diesel, eradication in use of kerosene, increased productivity as battery is charged in the house, reduction in pollution from diesel generators and reduction in health concerns due to lead acid exposure.

4.4. Installation Process

One system was installed in a household (HH1) to demonstrate the household level usage and the other system installed at the local primary school (HH2). Installing a system at the school was to raise awareness of the technology, as it is a central hub for the community. It also results in widespread access as the teachers at the school can use the system. A teacher and his family also live at the school and are able to use the system during the night. Thus, further demonstrating how the technology can be used at the household level.

The community members were involved in the installation of the system. This helped develop local skills and increases the potential for the installation of systems in the future. In addition, local involvement facilitated transfer of technical knowledge. For example, it initiated further discussions about the importance of installing the panel in an unshaded location with correct orientation but also taking into account the trade-off in tilt angle. Through trial and error, the principal of the school (pictured in Figure 5) successfully installed the panel on the roof of a classroom at the school, the correct orientation and with sufficient airflow behind.

Figure 4. SHS at the Local School (Rebecca Watts)

At the household (HH2), through a similar discussion with approximately 20 community members, an appropriate location for the panel was identified. A member of a neighbouring household attached the panel to the roof of the shed using locally sourced plastic cable, hooks and nails.

Figure 5. SHS at a Household (Rebecca Watts)

4.5. Potential Financing for the Installed SHS

As it was a pilot project consisting of two systems, with one providing public usage, the systems were a donation and no repayment arrangement established. Furthermore, it was not viable to employ someone to collect money from only one household. In order to investigate the financial viability, the following economic analysis was undertaken. For insight into potential financing arrangements, three scenarios were investigated:

1) Scenario 1 –user pays all capital costs upfront
2) Scenario 2 – user repays nominal capital cost through periodic instalments, with no subsidy, and
3) Scenario 3 – user repays nominal capital costs of through periodic instalments, with subsidy of a quarter of the system cost (US$32.25).

The value of the repayments was based on cost savings generated by systems, with the O&M cost is deducted.

Table 4

	Scenario 2	**Scenario 3**
System Cost	US$129	US$129

Subsidy	0	US$32.25
Evaluation Period	10 years	10 years
Avoided costs/year – recharge	US$19.50	US$19.50
Avoided costs/year – battery replacement	US$8.33	US$8.33
Repayment amount per year	US$25.33 for years 1-4 and $25.67 for year 5	US$25.33 for years 1-3 and US$19.25 for year 5
Maintenance costs per year	US$2	US$2
Discount rate	12%	12%

Economic analysis generally takes into account the impact of the interest rates. The interest free financing would be a consideration to incentivise users to transition to solar energy. Therefore, this cost of this financing would be born by those providing the product. The low repayment rate (US$25.33) is another incentive and provides an arrangement tailored to the financial capacity of the households. Table 5 details the economic indicators for the three scenarios, with the most favourable for scenario 3. The LCOE for all scenarios lower than the current LCOE, which ranges from US$2.47-US$3.26/kWh. Therefore indicating the systems are more cost effective than current sources.

Table 5

	Scenario 1	**Scenario 2**	**Scenario 3**
Net Present Value	US$29.86	US$45.58	US$64.33
Levelised Cost of Electricity	US$0.93/kWh	US$0.80/kWh	US$0.75/kWh
Simple Payback period	-	4.63	3.75

With the subsidy, the system would be repaid within four years, whereas without the subsidy the system would be repaid within five years. From this time onwards, the households would have access to free electricity. For scenario two and three for the first few years while the systems are being repaid, the households are no worse off as the current expenditure would be redirected to repay the systems. For scenario one, the user would be out of pocket for the first five years and only reap benefits after this. This indicates that the systems are financially viable and have the potential to provide an affordable source of energy.

5. Results From Installation

It is important to monitor the progress of the project, identify the impacts of the SHS and assess whether changes are needed for future SHS. Table 6 gives details the achievements of the project through key performance indicators (KPIs).

Table 6

Stage	**KPI**	**Value for KPI**	**KPI Achieved in Project**
Input	Technical	Land Labour	Negligible Two man hours per system
	Community	Number of awareness programs	One awareness program
	Financial	Funds used	US$258
Outputs	Technical	Number of SHS installed	Two
	Community Participation	Number of people with knowledge about solar energy due to project	22 people directly

	Capacity Building	Number of supporting activities	0
Short-term Outcomes	Access	Percentage of households connected with SHS	2%
	Affordability	LCOE of SHS vs. other sources	Electricity from SHS is free, but the LCOE is US$0.93/kWh for all upfront cost paid
	Usage	Hours of electricity used: From Solar Energy	Household: 2-4 hours/day School: 2-4 hours/day

5.1. *The Product (the SHS)*

The following analysis is drawn from a survey from the household (HH1), the principal and teacher that lives at the school (HH2). This information is presented describing the successes and limitation for the product (the SHS) and the process (the implementation).

5.1.1. *Successes*

The project was successful in initiating the use of solar energy. The systems have been used to charge mobile phones during the day but predominately used at night to power lights (for 2-4 hours generally between 6:30pm-9pm). This indicates the load profile versus the power generation profile and indicates user acceptance.

Both HH1 and HH2 have identified a desire to increase the size and capacity of the systems (a fan for HH1 and two computers for the school, HH2). It is important to understand the demands of the user and design solar energy solutions accordingly. This will ensure community development is enabled by by solar energy.

The most significant change in behaviour for HH1 has been a reduction in recharging of the car battery and the ability to charge mobile phones in their house rather than at neighbours house. This indicates not only an acceptance of the technology but a preference of the SHS over the the diesel charged battery. This change in behaviour generates the following impacts:

Economic: cost saving due to less frequent recharging (due to less usage) and replacing of the battery (due to less cycles per year). Increased productivity as the time previously spent taking the battery and phone to external sources can be spent on income creating activities.

Environmental: reduces the diesel-generators usage, thus lowering emissions.

Health/social: reduction in exposure to toxic gases and the toxic effects of lead absorption from recharging and recycling battery.

HH2 identified two significant changes in behaviour; Firstly, teachers at the school are able to charge their mobile phones at the school. Which has the following impacts:

Economic: teachers generate cost saving from previous charging source (i.e. if previously charged at a café) or from charge from their car battery at home. Furthermore, increased connectivity (through mobile phones) increases productivity.

Social: widespread awareness as all the teachers at the school now have access to solar energy. Increased access to information (due to increased access to mobile phones) also leads to empowerment.

Secondly, the teacher and family that live at the school have access to light during the night, thus eliminating the use of kerosene. This has the following impacts:

Economic: extended working hours due to high illumination of lighting at night and cost savings from the elimination of kerosene use.

Environmental: reduction in the use of kerosene reduces indoor pollution.

Health/social: reduction in the chance of burns and indoor fires, increased safety due to more lighting at night and increased education as the children of the family are able to study at night.

5.1.2. ***Limitations***

The system in HH1 has been used in conjunction with the car battery as is not of sufficient size or capability to entirely replace the car battery. This limits the economic, social and environmental benefits and fails to entirely demonstrate the potential for solar energy at the household level.

5.2. ***The Process (the Implementation)***

5.2.1. ***Successes***

The installation process and workshops were successful as there was a transfer of technical knowledge and two-way sharing of information. The feedback from the attendees of the workshops were positive, with a member from HH1 commenting:

"You explained [to] us very clearly about how to use and maintain this system."

Sambath, 2015, (Watts, 2015).

There was successful knowledge transfer about how solar energy works as HH1 was able to explain the functioning of the system, commenting

"The solar battery store power, even on the cloudy day we still can use light and charge phone."

Sambath, 2015, (Watts, 2015)

The workshops were successful in transferring knowledge about the operation and maintenance, as the systems have remained functional and have been maintained. This has ensured households can use the systems independently and reap the associated economic, social and environmental benefits.

5.2.2. ***Limitations***

Due to limited time and resources, only one education workshop was held and there was no training of a technician. Also, as only one SHS was installed in a household, no financing arrangement was established and the financial viability of the systems can only be predicted.

5.3. ***Conclusion***

Due to the high cost of electricity and lack of existing infrastructure in Cambodia, especially in rural areas, standalone solar home systems (SHS) have significant potential in providing a long-term, affordable and clean energy solution.

In conjunction with an educational workshop, two SHS were installed in the Secret Beach community, a rural community in Cambodia. This project was in initiating solar energy in the community, as it is the preferred energy source. For the users, SHS has reduced the recharging and replacing of the car battery and the eradicated the use of kerosene. This has generated cost savings due to reduced fuel costs, increased productivity due to timesaving and extended work hours. This has also reduced emissions from diesel generators and thus reduces the potential for severe diseases caused by the absorption of toxic gases and toxic effects of lead absorption.

The systems have also increased access to lighting, which has increased safety and permitted children to study at night. The reduction in kerosene also reduces the risks posed by inhalation of pollutants and unintentional ingestion.

The workshop successfully transferred knowledge about the functioning of solar energy and the operation and maintenance of SHS. By sharing knowledge, the community identified the advantages of solar energy over current energy sources.

The project has successfully initiated the use of solar energy in the community. SHS have proved to provide economic, environmental and social benefits to households in rural communities. Further installations of SHS has the potential to provide a clean energy solution and translate the outcomes (of this project) into long-term and widespread reductions in poverty, increased quality of life, economic development and environmental sustainability.

References

Asian Development Bank, 2014, 'Poverty Analysis (Summary)', Country Partnership Strategy: Cambodia, 2014–2018.

International Finance Corporation, 2012. 'Lighting Asia: Solar Off-Grid Lighting'. Accessed. 29 April 2015.

Ministry of Industry, Mines and Energy, 2013. 'National Policy, Strategy and Action Plan on Energy Efficiency in Cambodia.' Royal Government of Cambodia.

United Nations (UN), 2007. Cambodia Energy Sector Strategy. Accessed: 13 Mar. 2015.

Saly, K., 2014. Beekeeper Solar Project Research.

Watts, R,. *Survey of the Households in Secret Beach Community.* August 2015.

World Bank,. 2012. Rural Electrification and Transmissions Project. Accessed: 14 Mar. 2015.

2015 ASIA-PACIFIC SOLAR RESEARCH CONFERENCE

Appendix

Scenario 1 – All capital cost paid											Net Present Value		4
											Levelised cost of electricity		0
	Use per day (hrs)	Energy Output (kWh/yr)	PV of Energy Output (kWh/yr)	Avoided Costs (recharge)	Avoided Costs (battery replace)	Total Benefit	System cost	O&M cost	End cost to user	Total Cost	Net End-User Benefit	PV of end cost Net Benefit to User	T B
2016	4	22	19.64	19.5	8.33	27.83	129	2	129	131	116.96	-103.17	
2017	4	22	17.54	19.5	8.33	27.83		2			1.59	25.83	
2018	4	22	15.66	19.5	8.33	27.83		2			1.42	25.83	
2019	4	22	13.98	19.5	8.33	27.83		2			1.27	25.83	
2020	4	22	12.48	19.5	8.33	27.83		2			1.13	25.83	
2021	4	22	11.15	19.5	8.33	27.83		2			1.01	25.83	
2022	4	22	9.95	19.5	8.33	27.83		2			0.90	25.83	
2023	4	22	8.89	19.5	8.33	27.83		2			0.81	25.83	
2024	4	22	7.93	19.5	8.33	27.83		2			0.72	25.83	
2025	4	22	7.08	19.5	8.33	27.83		2			0.64	25.83	
2026	4	22	6.32	19.5	8.33	27.83		2			0.57	25.83	
Total			**130.63**								**127.05**		

Scenario 2 - Without Subsidy and interest free financing											Net Present Value		4
											Levelised cost of electricity		0
	Use per day (hrs)	Energy Output (kWh/yr)	PV of Energy Output (kWh/yr)	Avoided Costs (recharge)	Avoided Costs (battery replace)	Total Benefit	System cost paid by end user	O&M cost	Total End cost to user	PV of end cost	Net End-User Benefit	PV of Net End-User Benefit	S (V S
2016	4	22	19.64	19.5	8.33	27.83	25.83	2	27.83	24.85	0	0	
2017	4	22	17.54	19.5	8.33	27.83	25.83	2	27.83	22.19	0	0	
2018	4	22	15.66	19.5	8.33	27.83	25.83	2	27.83	19.81	0	0	
2019	4	22	13.98	19.5	8.33	27.83	25.83	2	27.83	17.69	0	0	
2020	4	22	12.48	19.5	8.33	27.83	25.67	2	27.67	15.70	0.17	0.08	
2021	4	22	11.15	19.5	8.33	27.83		2	2	1.01	25.83	11.69	
2022	4	22	9.95	19.5	8.33	27.83		2	2	0.90	25.83	10.43	
2023	4	22	8.89	19.5	8.33	27.83		2	2	0.81	25.83	9.32	
2024	4	22	7.93	19.5	8.33	27.83		2	2	0.72	25.83		
2025	4	22	7.08	19.5	8.33	27.83		2	2	0.64	25.83	7.43	
2026	4	22	6.32	19.5	8.33	27.83		2	2	0.57	25.83	6.63	
Total			**130.63**							**104.90**		**45.58**	

Scenario 3 - With Subsidy and interest free financing											**Net Present Value**	
											Levelised cost to end user	
Year	Use per day (hrs)	Energy Output (kWh/yr)	PV of Energy Output (kWh/yr)	Avoided Costs (recharge)	Avoided Costs (battery replace)	Total Benefit	Subsidy	System cost to end user	O&M cost	End cost to customer	PV of end cost	Net End-User Benefit
2016	4	22	19.64	19.5	8.33	27.83	32.25	25.83	2	27.83	24.85	0
2017	4	22	17.54	19.5	8.33	27.83		25.83	2	27.83	22.19	0
2018	4	22	15.66	19.5	8.33	27.83		25.83	2	27.83	22.19	0
2019	4	22	13.98	19.5	8.33	27.83		19.25	2	21.25	16.94	6.58
2020	4	22	12.48	19.5	8.33	27.83			2	2.00	1.59	25.83
2021	4	22	11.15	19.5	8.33	27.83			2	2.00	1.59	25.83
2022	4	22	9.95	19.5	8.33	27.83			2	2.00	1.59	25.83
2023	4	22	8.89	19.5	8.33	27.83			2	2.00	1.59	25.83
2024	4	22	7.93	19.5	8.33	27.83			2	2.00	1.59	25.83
2025	4	22	7.08	19.5	8.33	27.83			2	2.00	1.59	25.83

2026	4	22	6.32	19.5	8.33	27.83			2	2.00	1.59	25.83
Total			**130.63**								**97.33**	

Appendix V: The Design and Installation of Solar Home Systems in Rural Cambodia

Introduction

The second of two publications by Rebecca Watts about her work on solar home energy systems in rural Cambodia is presented in this Appendix. This article, published in the Journal of Humanitarian Engineering, emphasises the social engagement aspects and impacts of her work. This journal was established by EWB-A as an outlet for capturing and disseminating the outcomes from projects within the EWB Undergraduate Research Program.

The Design and Installation of Solar Home Systems in Rural Cambodia

Rebecca Watts
Engineers Without Borders, Melbourne Australia
rebecca_watts@live.com

Jeremy Smith & Andrew Thomson
Research School of Engineering,
The Australian National University, Canberra Australia

ABSTRACT: *This study contends that solar home systems (SHS) are an appropriate solution to provide affordable, reliable and clean electricity in rural Cambodia. SHS provide decentralised electricity suitable for the electricity needs of rural households and with the decreasing cost of solar energy technologies, SHS are becoming an increasingly competitive source of energy. This study details the design and installation of two SHS in a rural community in Cambodia. The SHS have replaced the use of kerosene lamps and supplemented car battery usage, which has generated a cost saving of USD$2.50-3.20 per month. The SHS have increased the hours of quality lighting making it possible for users to improve educational outcomes by studying at night and participating in private education classes as well as potentially extending their working hours that provides an opportunity to increase their income. Community involvement in the installation of SHS and participation in an education program has ensured transfer of knowledge about system operation and maintenance at a local level that has ensured economic, social and environmental were benefits. This study builds a case in support of solar energy at the household level in rural Cambodia and makes recommendations for the deployment of SHS in rural communities throughout the developing world.*

KEYWORDS: Solar energy, rural off-grid electrification, solar home systems, sustainable development

1 INTRODUCTION

Eighty per cent of the population in Cambodia lives in rural areas where access to grid electricity is as little as 18.8 % (World Bank, 2015). Due to dependence on expensive imported oil, losses in distribution and lack of high voltage transmission lines, electricity tariff in Cambodia is the highest in the Southeast Asian region (United Nations, 2007). Communities in rural areas use alternate energy sources that: are expensive, pose health risks, are potential fire hazards, and are damaging to the environment. An estimated 1.06 million rural households use kerosene lamps as their primary source of lighting and a further 1.12 million rural households (45 % of rural households) use car batteries charged at isolated battery charging stations (BCS) (International Finance Corporation [IFC], 2012).

The alternate energy sources are more costly than grid electricity and as 90 % of the poor live in rural areas, this cost disproportionally impacts rural households. The use of kerosene lamps accounts for an average 4.9 % of total expenditure for rural households (IFC, 2012). The lamps provide low illumination, which hinders activities at night such as, cooking and studying. Furthermore, the burning of kerosene emits health-damaging pollutants and can cause structural fires to houses, severe burn injuries and the unintentional ingestion of kerosene is a risk to children (Mills, 2012). The BCS emit tons of CO2 each year, are plagued with poor conditions which pose health threats to workers and due to inadequate infrastructure allow acid to spill into the public drainage system and contaminate the groundwater and surrounding soil (Ministry of Environment, 2004). The BCS rely on expensive imported diesel thus recharging batteries accounts for an average 4.5 % of total expenditure for rural households (International Finance Corporation, 2012). To give context to this lack of affordable energy access, the average expenditure on electricity in Australia is 2 % of household income (Australian Bureau of Statistics, 2013) while the average Australian electricity usage is over 300 times higher than a rural Cambodian household (10,400 c.f. 31 kWh/capita/annum).

The Royal Government of Cambodia has made progress towards extending the electricity grid however at least 30 % of Cambodian households are not scheduled to have access to the grid until 2030 at the earliest (Ferranti et al. 2016). Due to the ease of installation and appropriateness of the technology, solar home systems (SHS) are a disruptive method of improving energy access in Cambodia. The largest injection of SHS has come from two initiatives: The Rural Electrification Fund (REF) and The Good Solar Initiative. The initiatives have installed an aggregate 20,000 SHS, with an aim to roll out a further

20,000 and 25,000 respectively by 2018 (Ferranti et al. 2016). These initiatives comprise of SHS from numerous companies that have made comparatively lower private sales.

Despite the appropriateness of the technology, care must be taken in project implementation. There are many examples of electrification aid projects that have rapid cycles of installation to failure (Quoilin & Orosz, 2013). One such project occurred in the rural Secret Beach community in south Cambodia. A solar panel and battery system was installed in the community's local primary school in 2013 and was only operational for six months. The system was incorrectly sized and designed with no community consultation. Due to the absence of community involvement in implementation, there was a lack of local knowledge about the operation and maintenance of the system. This project implementation approach failed to create a sense of ownership and damaged the reputation of the technology. This study details a project completed by the author and a partner non-government organisation (NGO) in the Secret Beach community. The project rectifies previous failings by applying the principles of human-centred design and taking a participatory implementation approach.

2 SOLAR HOME SYSTEM BENEFITS

A community committee in Secret Beach identified electricity access as a priority to achieve economic development and increase quality of life (Saly, 2014). This study details a project that encompasses the design and installation of two SHS in the community to assess the appropriateness of SHS in achieving this vision. SHS consist of a solar panel, charge controller, battery and a load and the suitability of the technology is discussed below.

2.1 Affordable and suitable for small-scale, decentralised generation

The reduction in cost of solar panels (reaching less than USD$1.0 per Watt in 2015) (Fraunhofer, 2016) has increased the accessibility of solar energy technologies to low-income populations if accompanied by appropriate financing arrangements. Solar modules are sold according to the Watt-peak (Wp) and as the price does not scale with module size, they are appropriate for small-scale electricity generation (Advisory Group on Energy and Climate Change, 2010). SHS provide a decentralised energy supply, which is well suited to remote locations where grid extension is not economically viable like the Secret Beach community. Poor project implementation and lack of accessible financing options for households pose the most significant barriers preventing wide-scale roll out of SHS.

2.2 Reliabible and convenient

Car batteries, like those used in households in the Secret Beach community, are shallow cycle and are not designed for the current practice of overcharging and high depth of discharge. This practice reduces the lifetime of the battery that varies from eight to 24 months (Ministry of Environment, 2004),(Rijke, 2008). The SHS encompasses a deep-cycle battery that is more suitable for a high depth of discharge. The SHS also operates with a charge controller, which regulates the charging and discharging of the battery and thus increases the expected battery lifetime. As the battery is charged from the solar panel, the battery remains within the household. The time previously spent or cost incurred from transporting the battery to and from an external charging source (for example a BCS) can be spent on income creating or social activities.

2.3 Opportunity to implement clean and renewable energy technologies

The lack of existing electricity infrastructure in Cambodia presents an opportunity to leapfrog emissions intensive energy systems and satisfy growing demand through cleaner energy sources (United Nations [UN], 2010). Solar energy is a clean and renewable source and an energy system transformation to such technologies can support sustainable wealth creation while reducing the strain on resources and climate (UN, 2010).

3 SOLAR HOME SYSTEM DESIGN AND IMPLEMENTATION

The following sections detail the human-centred design of the SHS and participatory implementation approach in the community.

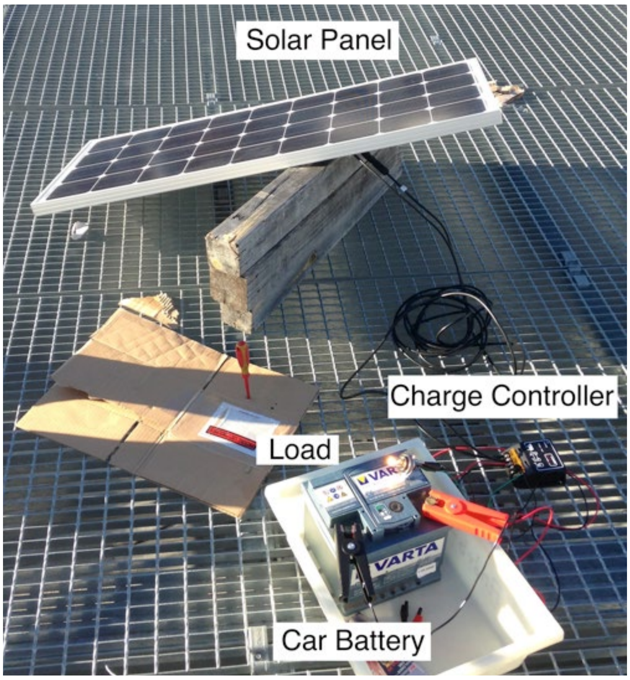
3.1 SHS design and prototype

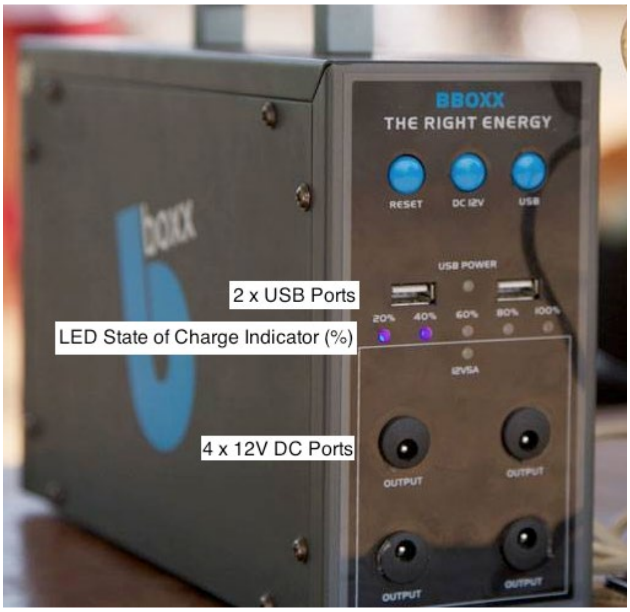
The human-centred design process starts with understanding the user (IDEO, 2015). Data about energy consumption, expenditure and the aspirations of the families in Secret Beach was gathered through a field visit by the author and community consultation (see Appendix 2). This consultation uncovered that the end-users prioritised: lights, phone charger, TV and fan and with main influencing factors being reliability and affordability. Based on this information, a SHS was designed to satisfy the user requirements and prototyped and tested, illustrated in Figure 1.

Assembling the prototype highlighted considerations for the final system configuration. Purchasing components individually allows for system customisability however requires a multistage wiring process and the system is vulnerable to tampering. Testing the system uncovered information to be communicated to the community, for example the decrease in panel output from shading and the importance of correct panel orientation.

3.1 SHS design and prototype

Based on an assessment of the usability, quality and price of the systems available in the market, the author, community and partner NGO decided the most appropriate SHS was the Bboxx BB7 (including a 15 Wp panel and 7 Amp-hour battery). The system satisfies the user





Top to bottom:
Figure 1: Photo of the model system
Figure 2: Control unit of Bboxx BB7 (Bboxx, 2015)
Figure 3: Solar energy workshop

requirements and is supplied by a suitable local supplier. The supplier provided the most comprehensive after sales support and importance was placed on this due to the lack of such support for the system installed in 2013.

Pictured in Figure 2, the Bboxx BB7 has an integrated control unit, which removes difficulties and complexities in system wiring. The infused casing reduces the chance of tampering or removal of the charge controller, which was an issue in previous SHS projects in Cambodia (Rijke, 2008). The battery (sealed lead-acid) is suitable for the generation and consumption profile of solar power and requires minimal maintenance (Power Sonic, 2009) which reduces health and safety concerns. These features address concerns identified in the prototyping stage, thus the final system design improved before reaching the end-user.

Based on community consultation, the two locations for the SHS were decided to be:

- At a household (HH1) whose family had expressed a desire to access solar energy; and
- At the local primary school (HH2) to provide electricity to teachers and students and the family who lives in the school office.

3.3 Economic viability

In 2011, 72 % of the population in Cambodia lived on less than US $3 per day (Asian Development Bank, 2014). The upfront cost of SHS like the Bboxx BB7 (RRP US $129) is unattainable for the majority of the population. Through further cost reductions in solar technologies and establishing efficient financing, SHS are becoming increasingly affordable for communities in rural areas. Appendix 1 indicates the affordability by investigating three hire-and-purchase arrangements. The arrangements are based on the model used to analyse the REF initiative (World Bank, 2012) and have similar payment periods currently offered in the SHS market.

3.4 Education and training

Education workshops (illustrated in Figure 3) were conducted with community members to raise awareness about solar energy and create user understanding about the operation and maintenance of the SHS. This education rectifies the shortcomings of the approach for the system installed in 2013. The workshops encompassed activities supported by visual tools, with material developed from research and learnings from the prototyping stage.

The activities included practical learning, for example participants practiced the operation and maintenance of the systems. Importance was placed on the communication method, as it is the process through which knowledge is shared, and determines whether learning occurs (Cummings, 2003). Through an open floor discussion, the participants shared their experiences with current energy sources and discussed the advantages of solar energy and the benefits of SHS. Development experts have identified that activities, which focus on facilitating knowledge sharing, are more likely to be successful than those focusing on transmitting Northern knowledge to South

Figure 4: Community involvement in installation

(Ellerman, Denning, & Hanna, 2001). The discussion both facilitated knowledge sharing and also indicated which information had been understood during the workshop. Thus, gaps in knowledge were explained to ensure a comprehensive understanding.

3.5 Community involvement in installation

With relevant training, community members were involved in installing the systems to develop local capacity for further SHS installation and create a sense of ownership. Community involvement also facilitated technical knowledge sharing. For example, the site for installation of the panel (Figure 4) was decided based on discussion about the importance of an unshaded location and the panel placed at the correct orientation.

4 MONITORING AND EVALUATION

As the SHS were purchased to trial the appropriateness of the technology, members of HH1 and HH2 (the users) committed to the author and partner NGO to provide feedback about user experience and system performance. The users were surveyed one, three and five months post installation to capture the initial and ongoing impact of SHS usage. There is often a lack of ongoing monitoring on similar projects. Survey results indicate the SHS have provided a reliable source of electricity and reduced usage of car batteries and kerosene lamps. The users have independently operated and maintained the systems and are able to explain to other community members how to the use systems. This information implies the workshops were successful in transferring knowledge. In addition, the workshop material was repeatedly used by community members for further training and increased the awareness of solar energy in the community.

The Most Significant Change (MSC) in behaviour is a method of participatory evaluation (Davies & Dart, 2005) that assesses the impact of technology through user stories. The MSC in behaviour for the SHS users and the associated economic, health/social and environmental benefits are described in Table 1.

5 RECOMMENDATIONS

There is significant potential for SHS to replace emissions intensive and expensive energy sources in rural households throughout Cambodia. Small-scale systems can have a significant impact on the lives of users by generating economic, social and environmental benefits as demonstrated in this study. This study provides insight into the design and implementation process of a SHS project and from this, recommendations for SHS projects in rural communities in Cambodia and other developing countries are outlined below.

5.1 Design considerations

- The SHS should be tailored to the user and the community should be involved in the decision-making throughout the project. This ensures the design is appropriate and community is empowered by the project.
- The SHS design and implementation process should be iterative, starting small scale and involve prototyping. This allows for user-feedback that ensures the design is constantly improving.

5.2 Implementation considerations

- Education should be provided to ensure systems are operated and maintained correctly. This will enable associated benefits to be generated and create user satisfaction.
- A local technician should be trained to provide local support and facilitate the expansion of SHS usage. This will assist in longevity of the SHS and create employment opportunities.

5.2 Project considerations

- A suitable user pays arrangement (see Section 3.3 and Appendix 2) should be established to provide access for low-income households and assist in the financial sustainability of the project.
- The project should leverage on existing strengths in the community, for example engaging organised groups and leaders within the community.
- Effective monitoring and evaluation tools should be established to capture user feedback and influence each iteration of the project. This ensures the project design implementation approach is constantly improving.

6 CONCLUSION

The project presented in this paper demonstrates the economic, social and environmental benefits SHS can generate for rural households in Cambodia. By taking a human-centred design approach, the project designed SHS that were suitable for users. Involving the community in project implementation built capacity and ensured technical knowledge was embedded locally. Successful monitoring and evaluation tools captured feedback from the users ,which validated that SHS can replace emission intensive and expensive energy sources. By providing

Table 1: MSC in behaviour for the SHS users and the associated economic, health/social and environmental benefits

MSC1: Members in HH1 have reduced the frequency of recharging their car battery and now charge mobile phones in their home rather than at a neighbour's home.	
Indicator	**Benefit**
Economic	Cost saving ($3.20 per month) due to reduced frequency of battery recharging. Increased productivity as the time previously spent taking the battery and phone to charge at external sources can be spent on income creating activities.
Health/social	Reduction in exposure to toxic gases and toxic effects of lead absorption from the battery.
Environmental	Reduction in emissions from BCS due to reduced frequency of battery recharging.

MSC2: Members in HH1 have run private education classes at night due to the increased hours of quality lighting.	
Indicator	**Benefit**
Economic	Extended working hours and potential to increase income.
Health/social	Increased education opportunities for children in the community.

MSC3: The teachers have charged their mobile phones at the school (HH2) rather than at their respective houses or at a café.	
Indicator	**Benefit**
Economic	Cost saving from previous charging source (either from café purchases or reduced frequency of battery recharging). Increased productivity due to increased connectivity from higher access to mobile phones.
Health/social	Increased awareness of solar energy as students and teachers at the school are exposed to the SHS. The ability to charge phone at the school has incentivised teachers to attend classes, which has in turn increased education for students. Increased access to information due to increased access to mobile phones.
Environmental	Reduction in emissions from BCS due to reduced frequency of battery recharging (as car batteries were used to charge mobile phones).

MSC4: The family that resides at HH2 have replaced kerosene lamp usage with high quality light-emitting diodes (LEDs). This has increased the hours of lighting and the quality of lighting, which has enabled the teacher (father of the family) to write his lesson plan and allowed the children read at night.	
Indicator	**Benefit**
Economic	Extended working hours and cost saving of US$2.50 per month due to the elimination of kerosene use.
Health/social	Increased education for the children. The extended work hours for the father has increased recreational activities and time spent with children during the day.
Environmental	Reduction in indoor pollution and reduced risk of burns and indoor fires caused by the kerosene lamp.

affordable, reliable and clean electricity SHS are thus an appropriate energy solution for rural households.

Given the lack of existing electricity infrastructure, the high and volatile price of electricity and remoteness of rural communities, SHS have huge potential in transforming energy usage in rural households. Rural communities comprise almost 80 % of the population in Cambodia and with the limited successful market penetration; there is a significant market for SHS. Increasing access will translate the benefits demonstrated in the project into widespread economic growth, poverty reduction and environmental sustainability. The author encourages prospective entrepreneurs, NGOs and the public and private sector to consider the recommendations made in this paper and increase the deployment of SHS.

7 REFERENCES

Advisory Group on Energy and Climate Change, 2010, *Energy for a Sustainable Future: Report and Recommendations*. United Nations, New York.

Asian Development Bank, 2014, *Cambodia: Country Poverty Analysis 2014,* Phillipines: Asian Development Bank.

Australian Bureau of Statistics 2013, 4671.0 - *Household Energy Consumption Survey,* http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/4671.0~2012~Main%20Features~Data%20availability~28

Bboxx 2015, *Solar Calculator,* viewed September 8 2015, http://www.bboxx.co.uk/solar-calculator/

Cummings, J 2003, Knowledge Sharing: *A Review of the Literature*, The World Bank Operations Evaluation Department, Washington DC: The World Bank.

Davies, R & Dart, J 2005, *The 'Most Significant Change' (MSC) Technique*, RJ Davies and J Dart, http://www.mande.co.uk/docs/MSCGuide.pdf

Ellerman, D, Denning, S, & Hanna, N 2001, 'Active Learning and Development Assistance', *Journal of Knowledge Management*, vol. 5, no. 2, pp. 171-179.

Ferranti, R, Fullbrook, D, McGinley, J, & Higgins, S 2016, *Switching on: Cambodia's Path to Sustainable Energy Sector,* Phnom Penh: Mekong Strategic Partners.

Fraunhofer Institute for Solary Energy Systems, *2016 Photovoltaics Report,* updated 11 March 2016. Fraunhofer ISE.

IDEO. 2015, *The Field Guide Human-Centered Design*, Canada: IDEO.org.

International Finance Corporation 2012, 'Lighting Asia: Solar Off-Grid Lighting' International Finance Corporation, World Bank Group.

Mills, E 2012, *The Lumina Project: Technical Report #10,* Lawrence Berkeley National Laboratory, University of California.

Ministry of Environment 2004, *Technical Report: Status of Used Lead Acid Battery Management in Kingdom of Cambodia,* Department of Environmental Pollution Control. Phnom Penh: Royal Government of Cambodia, Phnom Penh.

Ministry of Industry, Mines and Energy 2013, *National Policy, Strategy and Action Plan on Energy Efficiency in Cambodia,* Phnom Penh: Royal Government of Cambodia, Phnom Penh.

Power Sonic 2009, *'Sealed Lead-Acid Batteries: Technical Manual',* Power-Sonic Corporation.

Quoilin, S, & Orosz, M 2013, 'Rural Electrification through Decentralised Concentrating Solar Power: Technological and Socio-Economic Aspects', *Journal of Sustainable Development of Energy, Water and Environment Systems,* vol. 1, no. 3, pp. 199-212.

Rijke, K 2008, Strategy and Design of a Solar Shop in Rural Cambodia, masters thesis, Industrial Design Engineering, Delft University of Technology, http://www.kcstrategicdesign.com/kamworks_files/StrategyDesignSolarShopWEB.pdf

Saly, K 2014, *BeeKeeper Solar Research,* Unpublished.

United Nations 2007, *DRAFT: Cambodia Energy Sector Strategy* Agenda 21.

United Nations Secretary-General's Advisory Group on Energy and Climate Change 2010, *Energy for a Sustainable Future,* New York.

World Bank 2015, *Access to electricity, rural (% of rural population),* online database, World Bank, Sustainable Energy for all (SE4ALL) database from World Bank, Global Electrification database, viewed 26 March 2015, http://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS?locations=KH

World Bank 2012, *Implementation Completion Results Report: to The Kingdom of Cambodia for a Rural Electrification and Transmission Project,* Sustainable Development Department, Southeast Asia Country Management Unit, East Asia and Pacific Region.

APPENDICES

Appendix 1: Community survey

The partner NGO provided a survey of 19 households in Secret Beach on energy usage and sources of energy (Saly, 2014). The households were a sample selected as a representation of the entire community. Consistent with the research presented in Section 1, the households use a variety of energy sources. For lighting, the households use a combination of lights powered from disposable batteries (700 riel USD $0.175 per set), kerosene lamps (USD $0.875 per litre) and/or car batteries. The usage and expenditure on kerosene was not captured in the survey and will not be included in calculations. Car batteries were the predominant source of energy for the households and will be included in the economic analysis.

As a representation of the survey, Table 1 details the expenditure on recharging a battery and appliances used by three households. Based on the data the assumed usage in Watt-hours (W?hrs/day) and associated levelised cost of electricity (LCOE) were calculated.

Appendix 2: Economic analysis

As there were only two systems installed, one being at the school (a public place and with public usage), it was not viable to establish a user-pays financing arrangement. To provide insight into affordability and potential financing arrangements, the following section investigates scenarios for the repayment of the Bboxx BB7 (USD $129). To cater to the different financial capacity of rural households, three scenarios were investigated and described in Table 2. Scenario 1 is for the total cost to be paid upfront, whereas scenario 2 and 3 hire-and-purchase arrangements. This model is based on the model used to analyse the SHS initiative under the REF initiative (World Bank, 2012).

Key considerations to incentivise households:

- Repayments are interest free as the cost of financing is borne by the provider.
- A subsidy provided under scenario 3.
- The households are no worse off in any year as the repayment amount is equal to or less than the recharge and replacement savings, with the O&M cost deducted.
- Assumptions: The Bboxx BB7 is used in conjunction with the car battery; it therefore reduces the reliance on the battery. This in turn reduces the recharging and replacing frequency, with a cost saving of USD $19.50* and USD $8.33* respectively.
- The Bboxx BB7 battery would be replaced every 10 years. The long lifetime is due to the high quality battery and support services provided by the supplier.

Table 1: Household (HH) energy usage and expenditure in the Secret Beach community (Saly, 2014)

HH	Cost per charge (USD $)	Frequency of charging	Cost per day (USD $)	Capability	Approximate usage (W-hrs/day)	LCOE (US$/kWh)
1	0.75	Every week	0.11	TV, phone, lights	84	2.25
2	2 batteries, 0.50 each	Every week	0.14	Lights, 3 phones	42	3.62
3	0.8	Every four days	0.20	TV, Video player, lights, 2 phones	118	2.49

Table 2: Costing of SHS repayments for various scenarios

		Scenario 1	Scenario 2	Scenario 3
Initial Capital	Initial capital cost required by provider	USD $129	USD $129	USD $129
	Subsidy	USD $0	USD $0	USD $32.25
	Cost owing at year 0 for household	USD $0	USD $129	USD $96.75
Benefit for household	Avoided costs (from battery recharging)	USD $19.50 per year	USD $19.50 per year	USD $19.50 per year
	Avoided costs (from battery replacement)	USD $8.33 per year	USD $8.33 per year	USD $8.33 per year
Costs for household	Periodic installments	N/A	Year 1 - 4: USD $25.33 Year 5: USD $25.67	Year 1 - 3: USD $25.33 Year 4: USD $19.25
	O&M cost	USD $2 per year	USD $2 per year	USD $2 per year

- The O&M cost is USD $2 per year (includes $1 for a cloth and $1 for 2 litres of water).
- The increased productivity due to longer working hours and the reduction in time involved with transporting the battery and/or phones to external sources to be charged has not been included as a benefit.
- Evaluation Period is 10 years.
- Subsidy was one quarter as this was the subsidy proportion provided to households in the World Bank SHS initiative (World Bank, 2012).
- Discount rate is 12 % as this was the rate used in the World Bank SHS initiative (World Bank, 2012).
- According to the datasheet, the Bboxx BB7 provides up to 60 W-h/day. This is over half current of current electricity consumption from households (ranging 48 W-hrs/day-118 W?hrs/day). Therefore, it was estimated the batteries are charged half as often, saving half the recharge cost which equates to USD $19.50 per year. Furthermore, the reduced usage of the batteries means the batteries are to be replaced less frequently, it is estimated as every 2 years rather than every 3, saving one third of the replacement cost which equates to USD $8.33 per year. These figures are used to calculate the net benefits in Figure 5.

Figure 5 graphs the present value of the accumulated benefits under the various scenarios. In scenarios 2 and 3 the systems are paid off within five and four years respectively, after which the systems generate economic benefits and essentially "free" electricity (not including replacement costs). For scenario 1, the household would be worse off until year seven and only then reap benefits, illustrated by a negative present value of accumulated benefit in Figure 5. As no interest rate is charged, the NPV is higher under scenario 2 and 3 than under scenario 1.

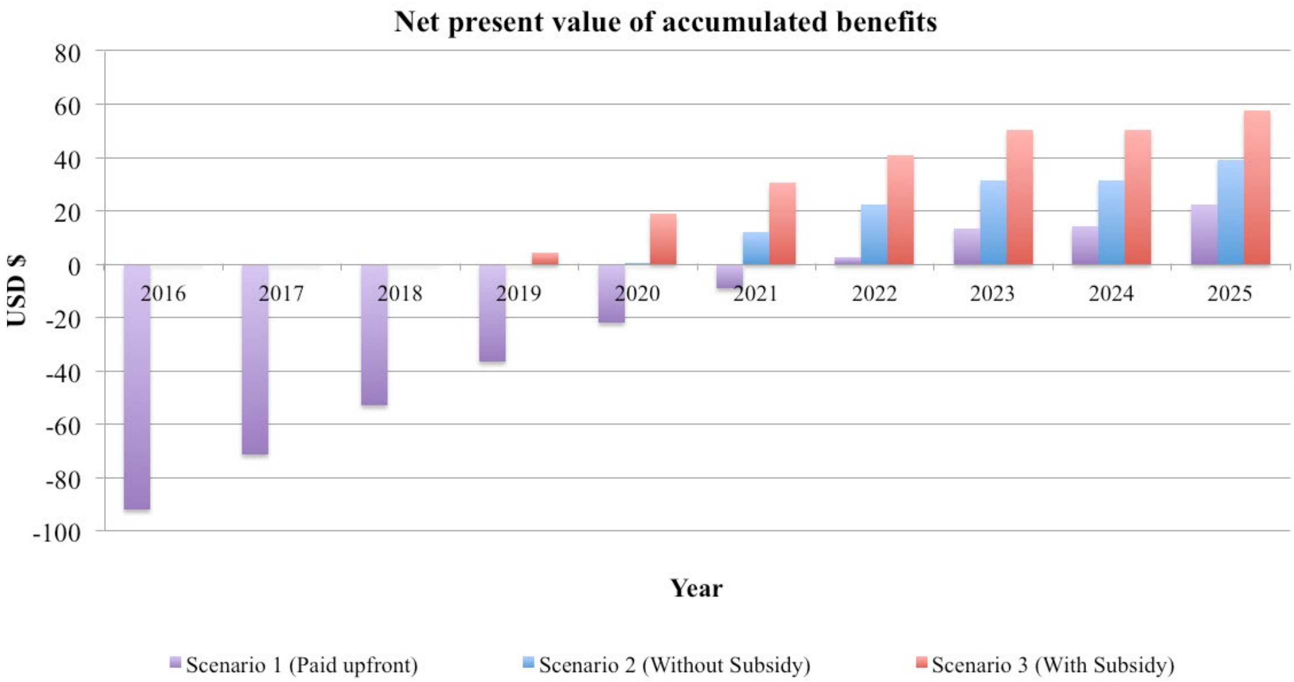


Figure 5: Net present value of accumulated benefits

Appendix VI: Perspectives of Solid Waste Management in Rural Cambodia

Introduction

This Appendix is the third and final in the trilogy of papers authored by students engaged in the Humanitarian Engineering pathway at the ANU. As with the previous two Appendices, the focus is rural Cambodia and explores perspectives of solid waste management. The research commenced after the lead author, Edward Creaser, completed an EWB Summit to Cambodia, and was completed as part of his final year individual research project. Half-way through his research, Mr Creaser attended a second EWB Summit to collect further data from the field. As with the previous Appendix, this article was published in the Journal of Humanitarian Engineering, as an appropriate channel for students involved with the EWB Undergraduate Research Program.

Perspectives of Solid Waste Management in Rural Cambodia

Edward Creaser, Jeremy Smith, Andrew Thomson PhD
Research School of Engineering, The Australian National University, Canberra, Australia
jeremy.smith@anu.edu.au

ABSTRACT: *We present perspectives of solid waste in the Cambodian community of Koh Dambang, situated on the Mekong River, identified through a field-based mixed-methods study. We found that Koh Dambang had no waste service and households were responsible for their waste management. The residents interviewed produce approximately* 0.4 *to* 1 *kg of waste per person per day, where typically half of the waste is burnt, a quarter is buried and the remainder is dumped. Our research highlighted the desire for a community-level waste management plan. Some degree of waste management centralisation would have environmental, health and economic benefits for the residents, where expert consultation on a community-level incinerator or alternative would also be beneficial, although this is embedded in our existing external perspectives of waste management. Further consideration of the views of the whole community and its administration is required before a strategy could be proposed.*

KEYWORDS: *Waste Composition, Waste Management, Cambodia*

1 INTRODUCTION

The collection and management of waste is vital for good health and environmental sustainability in developing and developed countries alike. In Cambodia, a growing population, societal development, and industrialisation has encouraged increased consumption of resources and waste generation per capita (Agamuthu et al. 2007, Parizeau et al. 2006). Within Cambodia's large urban centres, such as the capital Phnom Penh, waste collection and management systems have been implemented by the government with the contract waste collection company Cintri (Heng & Laptaned 2007, CINTRI 2016).

Rural areas in Cambodia have limited access to basic waste management as municipal and district authorities can be reluctant or unable to provide basic waste management services due to a lack of resources, legislation, environmental ethics, education or support networks (Glawe et al. 2004, Muny, 2016). Management of waste is dependent on various factors including local drivers, resources, and waste composition. For the 84% of Cambodians living in rural areas, alternative waste management practices are used, with common methods including: informal waste collection, burning, dumping and burying (Muny 2016, Vanda & Heilmann 2015). In both rural and urban settings, dumping and burning can contaminate the ground and be dangerous if people are directly exposed to the waste and smoke, especially if disease and bacteria are cultivating inside (Stauffer & Spuhler 2016, Zurbrügg 2002).

These challenges and practices are prevalent in the island community of Koh Dambang located on the Mekong River in northern Cambodia (see Figure 1). Accessible only by boat, Koh Dambang is home to approximately 200 people. There are no waste collection services provided by the local Stung Treng province authorities and no organised waste management system on the island. Reasons for this are limited accessibility to the island to collect and manage generated waste, the substantial costs associated with transporting waste off the island, the lack of shared space on the island for a communal waste site, and Stung Treng authorities prioritising other services over waste management in the Mekong area.

This work explores waste management in Koh Dambang, as an example of the current waste challenges for rural communities in Cambodia. To investigate this and provide insights, community attitudes, practices and waste profiles are required. The next section outlines data collection and analysis approaches used, followed by the results obtained. A discussion draws together the results and considers potential opportunities and barriers to more sustainable waste management for Koh Dambang.

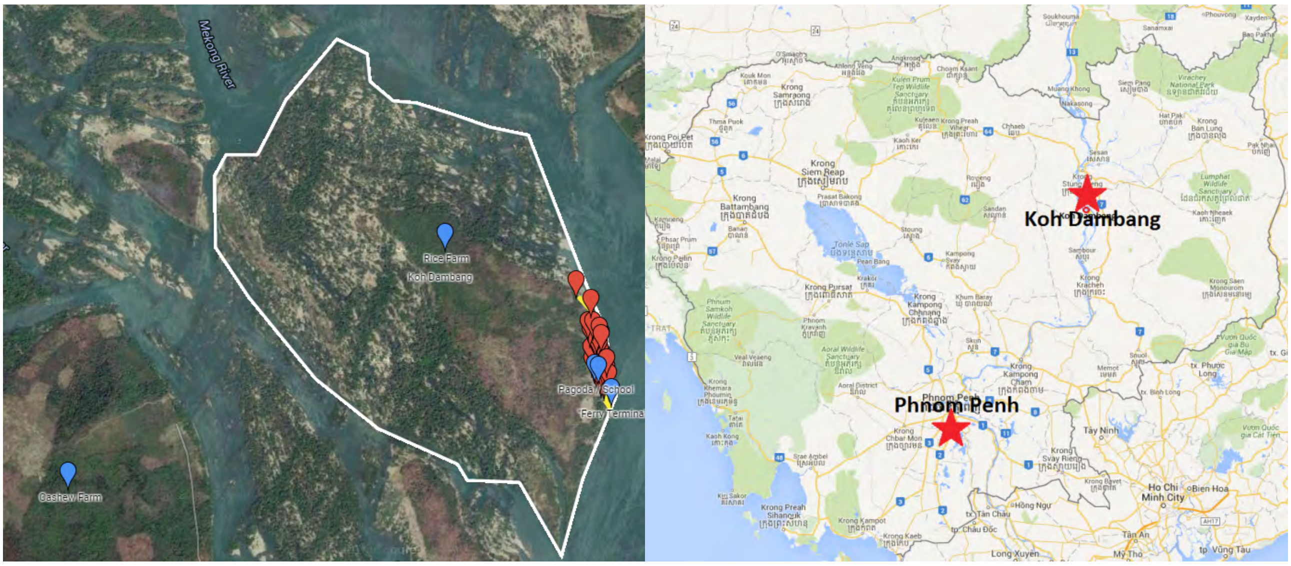


Figure 1: *The island of Koh Dambang (left), red arrows represent buildings (21 in total), and (right) the map showing Koh Dambang in relation to Phnom Penh (Google Maps,* 2016).

2 APPROACH

To investigate waste management in Koh Dambang a mixed-methods approach incorporating fieldwork and interviews was used. Interviews with residents captured the perspectives of Cambodians, which were supported by observations and solid waste analysis. Validity of research was examined by triangulating the three sources of data combined with existing literature, as shown in Figure 2. Fieldwork and data collection methods were developed in conjunction with Engineers Without Borders, Australia (EWB) and the AAA University and granted ethics approval.

The main fieldwork in Cambodia involved three days in Koh Dambang to engage with residents, observe current waste management practices, and understand the needs and interests of locals. The data collection methods used in Cambodia are outlined below.

Participant Questions and Conversations: Semi structured interviews on current waste management practices were conducted using the questions listed; the interviews were conducted in Khmer through a translator. Participant responses were recorded in a notebook during the interview process. All recorded information was qualitatively coded using an open coding style to identify and name common conceptual codes that emerged from participant comments. These codes were then grouped into common over-arching categories and reviewed by another member of the research team to give the framework for result analysis (Hoepfl 1997).

Photographs: Photographs were taken of waste and waste services around Koh Dambang. The photographs provided supporting visual evidence to participant responses.

Observations: General observations concerning disposal processes, behaviours, effectiveness, materials, and skills were undertaken during fieldwork to understand cultural and societal insights.

Solid Waste Composition: Observations included waste composition identification through measurements, volume estimation, participant responses to certain questions and photographs of waste.

3 RESULTS

During fieldwork in Koh Dambang, nine residents were interviewed (see Table 3). Participants were chosen based on their ability and willingness to explain their waste disposal practices, and were often senior members of their family. The categories arising from the qualitative coding are presented in Table 1, with respective sub-categories and sample comments.

Personal Roles and Responsibility: When it comes to the disposal of waste, there is no community or group based waste management system in Koh Dambang with all nine participants stating that they dispose of waste individually. Waste disposal is generally done by the female head of house with five out of the nine participants (Eoungh, Khim, Aai, Sarot and Hun) saying that they, or their wives, do the collection and disposal. The reason for this is noted by Som Aai saying 'she is in charge [of the rubbish disposal] as she is mostly at home. Husband is at work so away all day'. The other four participants said that both they and their partners help with collecting and disposing of the family's waste, with Soun Malim saying that 'she cleans or gathers rubbish. Her husband carries the rubbish to the forest to bury'.

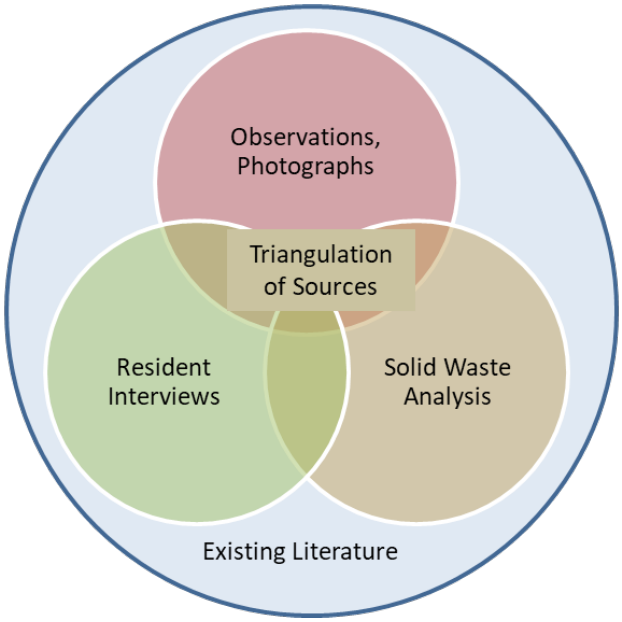


Figure 2: Triangulation of the information sources

Waste Disposal Practices: A variety of different waste disposal practices were identified including burning, dumping in the forest, and burying. Even though all participants burned at least part of their rubbish, the waste they burned varied. Five of the nine participants (Raksmey, Hun, Sreymom, Khim, and Aai) said that they burn all their combustible rubbish (paper, cardboard, plastic, textiles and dry organic matter) with Som Aai stating that she 'likes to burn rubbish behind her house'. The procedure to burn rubbish noted by Sem Hun is depicted in Figure 3.

This process of burning rubbish was visually observed when Han Sreymom swept up and placed various waste into a pile and ignited it by burning a piece of plastic or cardboard. The burn pile is shown in Figure 4a and Figure 4d. However, other community members (Eoungh, Sarot, Malum and Rai) prefer to burn just dry rubbish such as leaves and paper, with Soun Malim saying that she 'gathers dry leaves, paper, and burns'. The reason for this is stated by Elma Rai, who said she 'never burn[s] plastic bag[s] because she believes it is bad for her health'.

Table 1: Categories identified from responses from residents in Koh Dambang to the first set of questions

Categories	**Sub-categories**	**Sample responses**
Waste management	Waste disposal practices	Disposes [waste] in the forest far from house Burns rubbish every two days
	Reuse and recycling	Sells 1 kg of cans for 2,000 riel Uses bottles to store petrol or local wine
	Personal roles and responsibilities	Family individually manages their own rubbish Individual family member in charge of cleaning and disposing of rubbish
Waste characterisation	Waste composition	Separates plastic bottles, burns other useless rubbish 0.5 kg/day if just family
	Waste storage	Individuals keeps the rubbish in the bin
Barriers	Community member perceptions	Hard to convince people to dispose of rubbish properly Community wide [waste management] is hard, as different views of the importance to villagers
	Lack of alternatives	Doesn't know [any other methods], other than to bury, burn, or throw in jungle
	Disposal cooperation	Would be happy if the community wanted a [community wide waste management plan, (CWWMP])], but not sure if possible because there is little cooperation amongst villagers
	Health Considerations	Cambodian Rural Development Team (CRDT) told them about the health effects [of burning rubbish] so they burn [20 to 30 m] away from homes Never burn plastic bag because it is bad for health

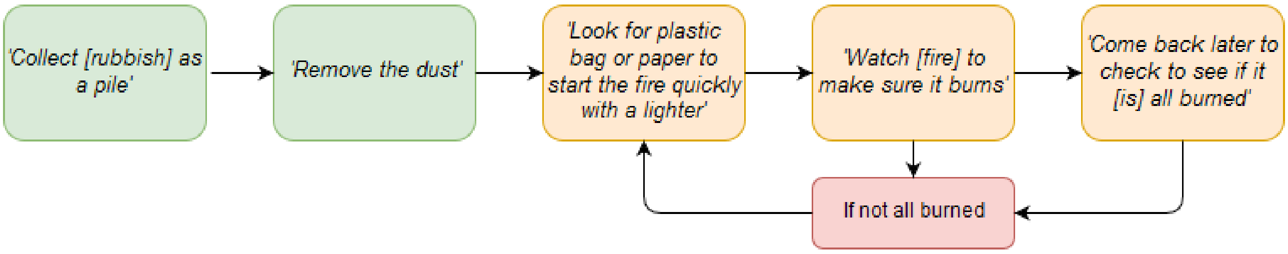


Figure 3: Flow chart of ad hoc burn pile burning procedure (Hun, 2016)

Figure 5 shows the respective approximate quantities of waste and its disposal method from responses, measurements, and observations. All participants burn some amount of rubbish, either as the primary method or secondary method (following sorting or disposal); this makes burning the most common disposal method, with burying and open dumping also remaining significant. This agrees with a comment by Kes Eoungh who said, 'everyone in the village burns rubbish'. The frequency of waste disposal varied across participants and their waste disposal behaviour. This information is summarised in Table 2.

It was found the temperature of burn piles, such as that in Figure 6, fluctuates sporadically. This is mainly due to extra combustibles such as cardboard being added onto the burn pile that ignites rapidly and intensely. Overall, the pile was mostly smouldering at temperatures around 180 to 250°C, far below the plastic and organic compound's complete combustion point of 500°C (Boettner et al. 1973) and 550 to 650°C respectively (EPA 2003).

Reuse and Recycling: It was found that most families do not separate waste into compostable and non-compostable materials due to limited individually owned crops or

Figure 4: Clockwise from the top left: a) Han Sreymom tending to her rubbish burn pile. b) Plastic bottles and cans stored by a community member. c) A small ceramic bin containing empty drink cans. d) Han Sreymom and her pile of organic, plastic and cardboard waste. (Photographed by Creaser).

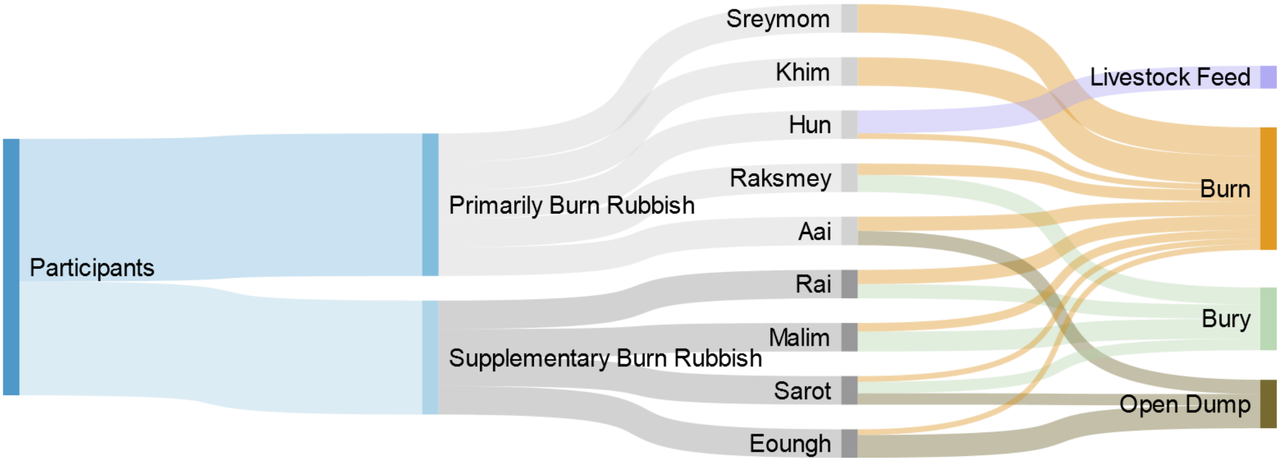


Figure 5: Sankey Diagram of the participants and their preference in waste disposal practices

Table 2: Disposal method and average frequency of disposal

Method	**Sample comment**	**Average frequency**
Burning	'every two days she disposes of rubbish by burning it'	Every three days
Dumping	'Three times a week he goes to the forest'	Every two days
Burying	'She buries rubbish once a week'	Every four days

Figure 6: Thick smoke from a small burn pile in Koh Dambang (photographed by Creaser)

incentive to do so. This is demonstrated with six of the nine participants not separating compostable waste, with Kes Eoungh saying that he has ‘no time to separate and doesn’t see why he should’. As for the other three participants, Elma Rai says that she ‘feeds chicken with the left over organic waste’ but participants like Sam Raksmey say that she ‘buries vegetation waste’. Residents often separate cans to sell to informal collectors who buy and transport the recyclables to the mainland by boat. Han Sreymom said that she ‘sells 1 kg of cans for 2,000 riel’ the equivalent of $0.65 AUD. Other noted uses for plastic bottles were pot plants or to ‘store petrol or local wine’.

Waste Composition: A day’s volume of waste generated by the families of participants Sem Hun and Sam Raksmey was separated into categories and weighed. In Figure 7, a Sankey diagram shows the characterisation of Raksmey’s waste along with the respective waste disposal method. Figure 7, shows that 46% of the measured waste is burned.

The amount of waste represented in Figure 7 was likely skewed due to do the inclusion of waste generated by visiting homestay participants living with the families during the fieldwork study. This would account for the discrepancy between the average waste generation rate reported by the families (0.4 kg to 1 kg of waste per day) and that observed during the study. The composition of the Raksmey family waste was observed to be similar to the other study participants.

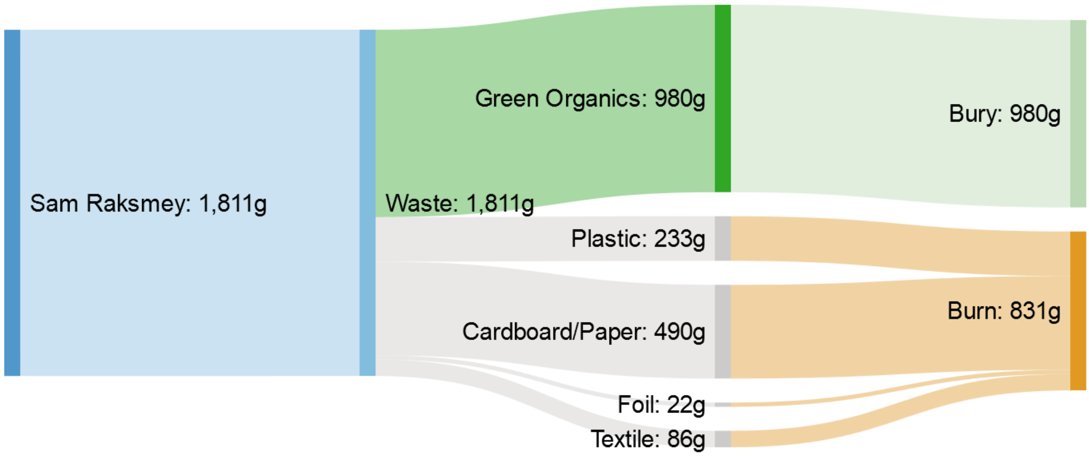


Figure 7: Waste type, weight, and disposal method of waste generated by participant Sam Raksmey's family

The Raksmey family's reported waste generation rate is comparable to other literature sources of waste generation in developing communities. Sethy et al (2014) reports a waste generation rate of 0.487 kg per capita per day for Phnom Penh in 2005, World Bank et al (2004) reported a waste generation rate of 0.3 kg per person per day for rural areas in Vietnam and 0.7 kg per person per day in urban areas in 2004. These values are however, over 10 years old.

It was observed that the residents' rubbish contained significant amounts of plastic. Two participants stated that their waste is 'mostly plastic bags' (Malim and Raksmey) with others saying that it is 'mostly plastic bag or paper boxes' (Sreymom, Sarot, and Eoungh) or 'mostly vegetable waste and plastic bags' (Rai). These comments are consistent with both Raksmey and Hun's rubbish measurements and anecdotal observations. Large quantities of plastic in the waste of Han Sreymom can be seen in Figure 4d along with green and dry organics and cardboard.

Waste Storage: All participants store waste in collection bins before disposal. Bins are either plastic bins with a lid or a simple cardboard box. Eoungh, Raksmey, and Aai stated that plastic bins are often lined with a plastic bag to contain the waste and is subsequently also disposed. The reason waste storage is practiced is due to local NGO, Cambodian Rural Development Team (CRDT), teaching residents of Koh Dambang proper waste storage for disease avoidance, as stated by CRDT worker Somboroth Dy.

4 DISCUSSION

4.1 Current Practices

It was found that for Koh Dambang, households are responsible for waste management. This matches findings from a survey of Municipal and District level administrations in Cambodia that found most agencies and district line offices believed that households should manage their waste through burying and burning. This was due to the belief that residents owned their land and hence had the resources available to handle their waste. (Muny, 2016)

There were four waste disposal streams for non-recyclable waste identified in the interviews:; burning, burying, dumping, and live-stockfeed or /re purposing. Another method identified method from literature is dumping of waste in the rivers. However, Waste dumping in rivers this is not practiced in Koh Dambang as community members believe that it is harmful to the ecosystem and unethical as the Mekong River provides support the local fishing industry and is a source of fish for food and income through a fishing industry as well as drinking water.

As shown from the burn-pile temperatures presented in Section 3, burning can occur at low-temperatures leading to dangerous particulates and gases from incomplete combustion. The extent of waste burned by participants varied due to the perceptions around health and safety. Soun Malim says that 'burying is better than burning because of the smoke' with Sem Hun also saying she 'believes that smoke causes a lot of problems to babies'. This leads to some participants burning their rubbish far away or preferring to use methods such as dumping or burying.

4.2 Alternatives Approaches

The current methods of waste disposal enact a large cost to community members both in time and physical effort. This is particularly true of the burning disposal method. Distance to dump sites, frequency of waste disposal, and the time taken to dig a hole to bury waste are all examples of cost factors associated with the current waste disposal methods.

When the community was questioned about alternative methods of waste disposal, the general consensus, as confirmed by the Chief Sa Khim, is that '[Koh Dambang] doesn't know any other methods [and] there is no transport of waste off the island'.

One alternative option is an organised community wide waste management plan (CWWMP). The idea of small-group waste management resonated with Sem Hun and Elma Rai who believe that it is 'better to do for only a small group - easier to cooperate, and discuss with like-minded people'. However, other residents saw potential issues. Kes Eoungh said that he 'wants [a] communal rubbish [plan], but thinks no one wants or cares about it, [and] no one will support him if he raises it'. It was expected that if a CWWMP were to work, the Chief stated that '[the community] needs an expert to come and teach them'.

As every participant's family disposes of waste individually, changing this social behaviour could be difficult. However, Han Sreymom mentioned that she disposes waste 'mostly individual[ly], but sometimes [a] neighbour helps out. If [a] neighbour's rubbish flies to her house, she will clean [it up] and vice versa', showing there is potential for communal waste management, especially in small groups who are like minded. However, further input from the residents is required to assess the options available to the community. This could consist of a survey based on the findings here to capture a more complete view of Koh Dambang residents, as well as perceived roles and responsibilities within community administration.

Options for CWWMP are burning, landfill, biogas and further recycling. With regular flooding and little available space, landfilling does not appear an appropriate option. An existing communal burning site on the rural island of Koh Pdao was noted by Ke Sarot. The burning site is a brick box, approximately one metric cube in volume (1×1×1 m), with a roof and chimney hole attached. Waste from villagers is placed inside and burned. It was implemented because 'someone in the community wanted it because Koh Pdao has a lot of tourism'. The communal contained burning example at Koh Pdao, may be a serve as a potential option for Koh Dambang, provided community support exists.

Supporting micro-businesses centered around recycling and/or waste management could be encouraged but may rely on external support which could limit their sustainability. For kitchen and garden waste management, small scale biodigesters could be utilised to generate fertiliser and biogas for cooking. However, the amount of waste generated may not be sufficient for household systems and, as with landfilling, flooding of the site can be a concern in the wet season. Further, as identified here, the majority of participants do not currently segregate organic compostable material from general waste.

External assistance for potential strategies is limited. Local NGO CRDT currently works in Koh Dambang to promote livelihood work to 'reduce poverty [and] conserve the environment' through regular visits. However, Somboroth Dy from CRDT, stated that 'waste management isn't a priority [because we are] not experts' but CRDT do 'tell impacts, provide [and] teach how to use rubbish bins, [and] raise awareness of keeping rubbish, burning it, [and] reusing [it]'. When asked if there are any other NGOs operating in the area who specialise in waste management, Dy said 'no NGO in [the] Mekong region [is] doing waste management'.

Koh Dambang is an example of the broader challenges present for solid waste management in rural Cambodia currently. As Muny (2016) highlights, within the current decentralisation policy of the National Government, responsibilities of the various administrative levels of government needs to be "further fine-tuned". Combined with the perception at District levels that households should manage their own waste, communities such as Koh Dambang may need to consider alternative options for sustainable solid waste management in at least the short and medium-term, including appropriate technologies and education programs (Vanda and Heilmann, 2015).

5 CONCLUSIONS

Increasing volumes of waste in rural Cambodia are proving difficult to manage. In these areas, it is the responsibility of individuals and households to manage their waste. Once green waste and immediately re-useable waste is removed, the majority that remains is buried, dumped or burnt. Burning, the most prominent disposal method, can be harmful, with incomplete combustion identified for small burn piles. Few community-led opportunities were identified, suggesting dedicated external support may be required to develop long-term sustainable waste management plans. However, comments from local NGO CRDT suggest that expert waste management support may be limited or non-existent within this region, despite local support by many community members for a long-term sustainable waste management plan.

6 ACKNOWLEDGEMENTS

The authors would like to thank all the participants in Phnom Penh and Koh Dambang for their involvement in the research and for providing answers to all the questions asked. We would like to thank Nick Brown and EWB Australia for providing the opportunity to conduct this research and supporting the first author's time in Cambodia.

7 REFERENCES

Agamuthu, P, Fauzaih, S, & Zhidzir, KN 2007, 'Sustainable waste management - Asian perspectives', *Proceedings of the International Conference on Sustainable Solid Waste Management,* Chennai, India, pp. 15 - 26.

Boettner, E, Ball, G, & Weiss, B 1973, *Combustion products from the incineration of plastic,* Washington, cat. no. EPA 670-2-73-049; PB-222 001, U.S. Environmental Protection Agency, National Environmental Research Center, Office of Research and Development.

CINTRI. (2016). *CINTRI (Cambodia) LTD*. Retrieved September 6, 2016 from http://cintri.com.kh/

EPA 2003, *Air Pollution Control Technology Fact Sheet*: *Thermal Incinerator,* United States Environmental Protection Agency.

Glawe, U, Visvanathan, C & Alamgir, M 2004, *Solid Waste Management in Least Develop Asian Countries - A Comparative Analysis, Bangaladesh*: Asian Institute of Technology, Department of Civil Engineering, Thailand.

Heng, N, & Laptaned, U 2007, 'Green logistics affecting the involvement of households in recycling and reuse of plastics', Proceedings of the International *Conference on Operations and Supply Chain Management* Phnom Penh, Cambodia, pp. 285 - 292.

Hoepfl, M 1997, 'Choosing qualitative research: a primer for technology education researchers, *Journal of Technology Education,* vol. 9, no. 1, pp. 1 -10.

Muny, M 2016, *Survey Report on Waste Management Practices At Municipality/District Level,* The National League of Local Councils

Parizeau, K, Maclauren, V, & Chanthy, L 2006, 'Waste characterisation as an element of waste management planning: Lessons learned from a study in Siem Reap, Cambodia', *Resources, Conservation and Recycling,* vol. 49, no. 2, pp. 110 - 128.

Sethy, S, Sothun, C & Wildblood, R 2014, 'Municipal solid waste management in Cambodia', in *Municipal Solid Waste Management in Asia and the Pacific Islands Challenges and Strategic Solutions,* Pariatamby A & Tanaka, M (eds,), Springer, Singapore

Stauffer B, & Spuhler, D 2016, I*ncineration* (*Small-Scale*). Sustainable Sanitation and Water Management (SSWM).

Vanda, K & Heilmann, D 2015, *Waste Management Challenges in Cambodia and Experiences from other countries,* Parliamentary Institute of Cambodia

World Bank 2004, *Vietnam Environment Monitor* 2004 *Solid Waste*, World Bank in Vietnam

Zurbrügg, C 2002, 'Urban solid waste management in low-income countries of Asia - how to cope with the garbage crisis', paper presented to: *The Scientific Committee on Problems of the Environment* (*SCOPE*): *Urban Solid Waste Management Review Session,* Durban, South Africa, November 2002, viewed 08 Oct 2018, https://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/publikationen/SWM/General_Overview/Zurbruegg_2003_Crisis.pdf

Appendix VII: An NGO-University Partnership for Sustainable Engineering Research Solutions

Introduction

The lead author for the article in this Appendix was Nick Brown, the then EWB Undergraduate Research Program coordinator at Engineers Without Borders Australia (EWB-A). It focuses on the EWB University Partnership Model using the partnership with the ANU as a case study of the model, highlighting how the collaboration has grown, the benefits for both organisations, and some challenges and lessons learnt. The partnership approach captured within the article is the basis of the community-focused projects and work undertaken within the Humanitarian Engineering pathway at the ANU. Student engagement and research work is built on partnerships with community groups and social enterprises. This provides for long-term relationships and programs, with greater opportunity for benefits to all collaborators involved. The ANU was one of the first universities to be a formal university partner with EWB, with the annual partnership being renewed every year since 2010.

An NGO-university partnership for sustainable engineering research solutions

Nick Brown and Peter Baynard-Smith, Engineers Without Borders Australia; Jeremy Smith, Andrew Thomson and Chris Browne, Research School of Engineering, The Australian National University

The 2030 development agenda laid out by the UN Sustainable Development Goals (SDGs) sets ambitious global targets for sustainable development. Australian engineering graduates must be motivated to face and be capable of tackling global issues such as poverty and disadvantage, as they have a critical role to play in achieving the SDGs. Even before the SDGs were launched, UNESCO stated that 'now and in the years to come, we need to ensure that motivated young women and men concerned about problems in the developing world continue to enter the field in sufficient numbers' (UNESCO 2010). Engineers Without Borders Australia (EWB) has developed engineering education initiatives, as described by Smith et al. (2016), that promote humanitarian and socially conscious engineering practices. In the broadest sense, humanitarian engineering can be considered the application of engineering skills, principles and practices to address short- or long-term disadvantage and vulnerability in domestic and international contexts (Turner et al 2015).

EWB's initiatives provide opportunities to Australian university students to learn about development perspectives in engineering through real projects. These projects empower students to participate directly in community based programmes and activities focussed on sustainable development and poverty alleviation. These opportunities are embedded within a formal university curriculum or are available to students informally through involvement in EWB as a member. Close collaboration is necessary and essential to ensure the goals and impact of these initiatives is achieved. One collaborative programme coordinated by EWB is the Humanitarian Engineering University Research Program.

Humanitarian Engineering University Research Program (URP)

The Engineers Without Borders URP was established in 2006 (Smith et al 2009) as an innovative initiative that directly engages universities in the challenges and opportunities of working with disadvantaged or marginalised communities in Australia and overseas. The real world context is vitally important and aims to address UNESCO's call for '…mobilising the engineering community to become more effective in delivering real products and services of benefit to society, especially in the developing world, is a vitally important international responsibility' (UNESCO 2010).

Whilst student learning and the generation of new knowledge and technologies for communities are short-term aims, the long-term aim of the URP is to create a substantial and sustainable community of engineering academics, practitioners and institutions committed to sustainable development research and impact. Specifically, the programme aims to:

- Support the humanitarian and development sector with solutions derived from innovative humanitarian engineering research.
- Increase the capability and motivation of engineering graduates to achieve EWB's mission (and by extension the SDGs); and
- Ensure there is a sustainable number of engineering academics and institutions conducting humanitarian engineering research.

To achieve these aims, the URP engages passionate academics and students at universities in Australasia through collaborative research projects that investigate challenges and needs posed by practitioners and community development organisations. Projects are most often conducted as part of a students' final year research projects and also through final year group capstone design projects. Student research is supported by their home university through access to facilities and expertise. To match existing structures, the projects are sometimes considered 'industry projects' with EWB or the development organisation acting as the client.

A research project is essentially a collaboration between EWB, a university and a development organisation that each benefit from participation in the programme. For EWB, these projects amplify its research outputs—one programme coordinator manages dozens of projects rather than having to conduct all of the research in-house. For universities, access to the URP includes access to around 40 defined research topics that can be integrated into their research offerings. Academics can have their work supported by EWB, and exposure to real world issues and challenges is often a strong motivator for students.

Benefits of the URP

Community development organisations and NGOs, who are the primary recipients of the URP research and development, benefit by receiving low-cost access to knowledge and technologies outside the scope of their core practice. The barriers that prevent practitioners from conducting the research themselves broadly fall into four categories.

1. *Capacity*: For smaller organisations that might be focussed on development implementation there is insufficient time for staff to spend on research and development. Students, however, have time as the projects are built into their curriculum.
2. *Capability:* In some instances, staff in organisations are experts in community development or human centred design, but lack

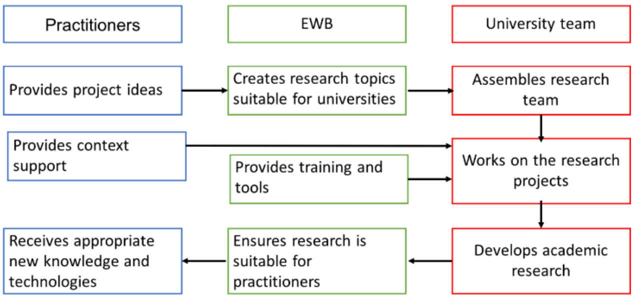
detailed engineering knowledge. Engineering academics and final year students may have this knowledge.

3. *Resources:* There is often a lack of access to assets such as computer software, testing spaces or lab equipment. For example, a previous research project involved recreating a slum dwelling inside a sealed laboratory in order to measure indoor air pollution caused by burning wood. These resources may not have been available to an organisation working in the slums of Mumbai.
4. *Innovation:* Many organisations end up with the same solution time and time again. Students are highly innovative and can sometimes develop new solutions or see a problem in a new light.

The EWB URP process

The process for a typical project is shown in Figure 1. In the collaboration, EWB essentially acts as the interface between the community development organisations and the university researchers. EWB has knowledge to work across both sectors and translates ideas from practitioners into projects for universities that align with the governing Australian Qualification Framework.

Figure 1: Project process across EWB, universities and practitioner organisations

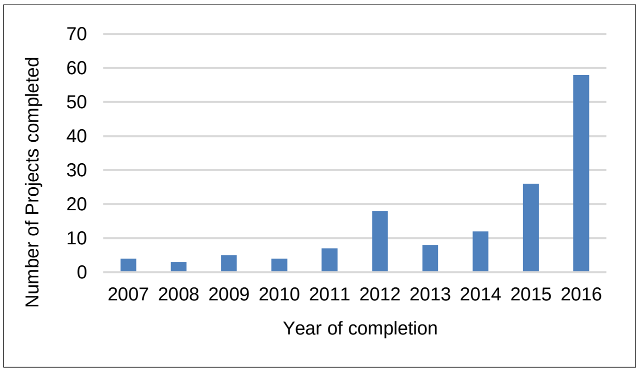


Through the project process, EWB supports students to produce outcomes that are valuable for partners and project recipients. This includes running workshops on humanitarian research skills, requiring reverse project briefs[1], and providing contextual support. The goal here is to take pressure away from the practitioners and provide support to academics who might be able to provide research support but may not have a full understanding of the context.

To achieve its aims, the URP utilises a service-learning educational approach. Here, students provide a 'service' to an external partner while receiving formal course credit from their institution to recognise the learning achieved. Service learning is becoming more common in engineering education around the world as a way for students to undertake a real project that empowers them to understand the broader context of engineering practice. Service learning is common in the United States where programmes such as the Engineering Projects in Community Service (EPICS) programme (Zoltowski and Oakes 2014), Service Learning Integrated throughout a College of Engineering (SLICE)[2] (Duffy et al 2011), Global Teams in Engineering Service (TIES) programmes (Bratton 2014) and the Louisiana State University Community Playground Project (Lima 2014) have been established and operated over extended periods. As one of the largest programmes, EPICS was established at Purdue University in 1995 to connect engineering students to a range of projects and community partners. EPICS has been replicated at multiple universities in the US (Zoltowski and Oakes 2014). Although the same framework and process may be used at multiple universities, each is responsible for the administration of their own programme including building and maintaining relationships with external partners.

In contrast to US programmes, the EWB URP centralises much of the project administration and relationship management. This works well in the Australian context, which has a smaller overall number of NGOs and universities and potentially less resources available for universities to engage with community partners in service learning. It provides the opportunity for academics without a background in development or community engagement to be involved with projects with a smaller initial time commitment.

Figure 2: Number of completed projects by year in the EWB URP



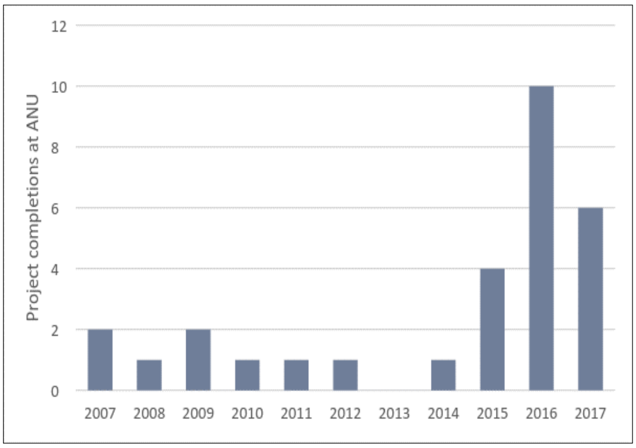
Since 2007, the URP has conducted over 200 collaborative research projects with dozens of development organisations, as shown in Figure 2. The growth in projects seen since 2015 can be attributed to an increase in resources for coordination of the URP as well as the establishment of the EWB Humanitarian Design Summit in January 2015. EWB Summits are two-week international experiences to countries including India, Malaysia, Samoa, Cambodia and Nepal, which introduce students to humanitarian engineering, user-centred design, and community development and engagement.

Case studies of collaboration between EWB and the ANU

The research collaboration between EWB and the Research School of Engineering at The Australian National University (ANU) is one of the longest within the EWB URP. The ANU was the first university to officially participate in 2007 and since then 29 research projects have been completed (or commenced in the first half of 2017) as shown in Figure 3.

The trends shown in Figure 3 at the ANU follow those for the EWB URP as a whole in Figure 2. In addition to the impact that the increase in resources to EWB have had on projects since 2015, the increase at ANU can be attributed to additional interest in the area due to the EWB Summits

Figure 3: EWB research project completions at ANU since 2007 (2017 data shows projects that commenced in the first half of the year)



as well as the establishment of a dedicated elective in the area. Launched in mid-2015, this elective, Engineering for a Humanitarian Context (EfaHC), provides a dedicated course for students interested in the area, creating an elective pathway available to all engineering students through a combination of project-based courses (such as group design and individual research projects), and international experiences (such as the EWB Summit). The final year research project thesis provides students with the opportunity to demonstrate and apply the humanitarian engineering knowledge and skills they have acquired. As an interesting aside, EWB projects at the ANU are attracting a higher percentage of females, 35 per cent compared to the overall participation of 22 per cent in engineering at the ANU.

A synopsis of three projects from the EWB URP undertaken by ANU students in 2015 and 2016 outlining the topic, partners involved and outcomes achieved follows.

Project title: Harnessing solar: A solution for rural Cambodia's energy needs

Rebecca Watts

On her visit with the EWB Summit, Rebecca investigated the energy situation of Secret Beach, a rural, coastal community supported by the Australian NGO Baby Tree to provide quality education to local children. Rebecca found that residents were charging car batteries at diesel recharging stations, costing both money and time. She found that the diesel recharging stations could be economically replaced with solar panels. On a second visit with the EfaHC course three months later, she installed two household level photovoltaic (PV) and battery systems and followed up with residents on the efficacy of the systems. Outcomes from this project included a journal article in the *Journal of Humanitarian Engineering*, a conference paper in the Asia–Pacific Solar Research Conference, an ANU Student of the Year Award 2015, and successfully installed operational solar systems. Upon graduation, Rebecca commenced a 12 month field job placement with EWB in Cambodia furthering her work.

Project title: PV micro-grid build-own-operate business models for energy services in refugee camps

Marta Irene Feria Cerrada

In 2016, Marta investigated the energy systems of displaced peoples in camps with the United Nations High Commissioner for Refugees (UNHCR) and considered the economics of setting up micro grids.

Marta looked at three cases:

- supplying the community with PV electricity for lighting and phone charging;
- supplying the administrative and health facilities with PV electricity; and
- a combination of the two.

She found that for most camps in the Middle East and North Africa, PV could cost effectively displace diesel generation. She took part in the EfaHC course at the start of her project, and while field work was not undertaken, Marta did survey a Médecins Sans Frontières logistician on the assumptions used in her modelling. Outcomes included a journal article on development targeting in the *Journal of Humanitarian Engineering*, the Industrial Engineering and Telecommunications (Madrid) Award for Engineers in Development, and a full time job in Madrid.

Project title: Rubbish in rural Cambodia—a step towards sustainability in communities

Ed Creaser

Following his participation in the EWB Summit in 2016 where his team explored waste management, Ed collaborated with the Cambodian Rural Development Team (CRDT) investigating the waste disposal situation for a community living on an Island in the Mekong. Initially Ed set out to investigate whether the waste situation could be improved by moving the burning of waste from piles to a formal incinerator. The true value and success of this work was the study and data collection on waste management in Cambodia including the rural village, which is providing aims and priorities for future projects. A journal article capturing the community engagement, perceptions and fieldwork is being developed for JHE.

Engagement with the programme

The EWB URP at ANU has involved seven different supervisors since 2007. The reasons for academics to engage with the programme include:

- access to EWB, its networks and through it, a range of community and practitioner organisations;
- ongoing relationship management with external partners;
- alignment with EWB Summits as preparation for students and potential for fieldwork and data collection; and
- immediate access to project topics, including the real-world focus as well as the convenience of having a topic prepared in advance that can be incorporated into coursework.

Informal feedback on outcomes by students, supervisors and partners has been positive with students reporting high levels of motivation for undertaking their projects as well as more significant learning as this feedback shows:

> Undertaking an [EWB service-learning] honours project in humanitarian engineering [at the ANU] changed my view of engineering, and connected my learning to the real world—a world that could be improved through solving problems using my skills as an engineer (ANU Engineering EWB URP Student 2009)
>
> My greatest achievement [as a student at the ANU] was undertaking and completing my final year honours project. I learnt so much, and it was very rewarding to look back on my work and see what I had achieved (ANU Engineering EWB URP Student 2016)

ANU has established partnerships with other humanitarian engineering organisations with collaborations and regular project opportunities available through Enable Development and Abundant Water (both of which were established by ANU graduates) and TADACT (Technical Aid for the Disabled ACT). Due to the increase in student interest since 2015, an informal research group has been formed in the area—the Humanitarian Engineering and Educational Development Research Group (HEERG)—to provide a focus and support network for students and academics. The group serves to build a community of practice, which can be particularly helpful for first time supervising academics who may have no previous engagement with EWB or community development, providing a base for potential integration of research and expertise into longer-term research including postgraduate projects.

Discussion and lessons learnt

Key to the success of the research partnership between the ANU and EWB has been the involvement of staff from both organisations in a range of projects building from shared goals and a solid working relationship. As part of the broader collaboration, three academics from the ANU gained humanitarian engineering knowledge by participating in EWB's Summits as academic mentors. These academics provide firsthand accounts of the development goals achieved under the programmes as well as explored potential research areas themselves.

The design of the URP enables academics and institutions to be involved based on their interest and commitments. At the ANU, this has allowed academics and students to build their expertise in a specific area and has led to three further partnerships being established with community organisations. The establishment of the HEERG at the ANU has created a hub to which other academics can affiliate. The model incorporating both research opportunities and curriculum development has been successfully used by other universities with which EWB partners. Key benefits are:

- URP attracts highly motivated and engaged students (not only academically capable);
- participation in EWB Summits as preparation for students;
- the experience is formative to both students and academics;
- the opportunity to disseminate research and outcomes in the *Journal of Humanitarian Engineering* upon completion of research projects;
- building on research partnerships to support collaboration on curriculum development, such as at the ANU with the EfaHC course;
- student understanding of the role of research, as projects are often complex due to their context, and from this students begin to recognise that small incremental change is typical and important; and
- a much greater participation from females in engineering education.

In establishing the partnership for the URP between EWB and the ANU, a number of lessons can be drawn for other institutions and programmes addressing the UN SDGs through research and development:

- Collaborations need to evolve from shared missions and visions built on long term partnerships;
- partners need to acknowledge and build from individual strengths and expertise;
- partnerships should provide additional opportunities to build expertise and knowledge to support and strengthen outcomes. For example, opportunities for supervisors to participate in EWB Summits help provide greater depth in supervision of projects .Benefits must be clear and identifiable for all stakeholders. The structure of the URP makes it easy for supervisors and students to integrate projects into existing coursework. Partners gain access to resources and expertise beyond their capacity. EWB is contributing to ongoing research and practice improvements across the field of humanitarian engineering and the SDGs.

Conclusions

EWB's URP is providing benefits to participating students, supervisors and community partners. Long term collaborations between EWB and universities like the ANU have been shown to create a stable platform from which engineeering-focussed, sustainable development research can be conducted. These collaborative programmes empower university students and staff to engage with challenges and opportunities faced by practitioners, to enhance development impact related to the SDGs. Stakeholder engagement and management of expectations have proven to be crucial skills in ensuring the success of the programme.

Notes

1 A reverse brief provides an opportunity for the project coordinator to discuss their brief with students to ensure students understand the research process and to identify any additional support the students may need.

2 Service-Learning Integrated throughout a College of Engineering (SLICE).

References

Bratton, M 2014, ‘Global TIES: Ten years of engineering for humanity’. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, 205–221.

Duffy, J, L Barrington, C West, M Heredia and C Barry 2011, Service-learning integrated throughout a college of engineering (SLICE). *Advances in Engineering Education*, 2(4), 1–23.

Lima, M 2014, The LSU community playground project: Reflections on 16 years of an engineering service-learning program. *International Journal for Service Learning in Engineering*, 9.

Smith, J et al 2016, Integration of a short-term international humanitarian engineering experience into engineering undergraduate studies. In *American Society for Engineering Education: 123rd Annual Conference*. New Orleans: American Society for Engineering Education. Available at: https://www.asee.org/public/conferences/64/papers/15508/view.

Smith, J, L Brown and A Cahill, 2009, Engineering social change: Engaging undergraduate engineers in community development research. *Australian Association for Engineering Education Conference*, pp.650–655. Available at: http://cecs.anu.edu.au/files/AE090106.pdf.

Turner, J, N Brown and J Smith, 2015, Humanitarian Engineering—What does it all mean ? In *26th Australasian Association for Engineering Education—Annual Conference*. AAEE. Available at: http://www.aaee.net.au/index.php/resouces/downloads/conference-papers-2015/13-1d-brown/file.

UNESCO 2010, *Engineering : Issues Challenges and Opportunities for Development*, UNESCO Publishing. Available at: http://unesdoc.unesco.org/images/0018/001897/189753e.pdf.

United Nations 2015, Transforming our world: The 2030 agenda for sustainable development, 70/1(October), 1–35. Available at: http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E.

Zoltowski, C, B and WC Oakes, 2014, Learning by doing: Reflections of the EPICS program. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, 1–32.

Appendix VIII: Humanitarian Engineering Education - Providing an Opportunity for a New Generation of Engineers

Introduction

In this final section of the thesis, a position statement developed collaboratively between the Humanitarian Engineering Education Network of Australia (HEENA which has now become HENA - the Humanitarian Engineering Network of Australia) and ACED (Australian Council of Engineering Deans) in 2018 is provided. This incorporates elements from the conference article in Chapter 3. It lays out the potential for Humanitarian Engineering in Australia and priority areas for the continued sustainable growth of the field. Captured within the statement is the recent growth and impact of Humanitarian Engineering in Australia, particularly its rise since 2015, which coincides with this study. The statement outlines the work required to fully realise the potential of Humanitarian Engineering for positive change and impact throughout engineering in Australia as well as the individuals and communities that the profession serves.

Position Statement **April 2018**

Humanitarian Engineering Education **Providing an opportunity for a new generation of engineers**

The Vision

The role of engineering in providing benefits to society has been articulated since the first civilian professional associations emerged in the early 1800s. From this tradition, engineering has sought to bring expertise and benefits to short- and long-term humanitarian responses and domestic and international development work. The incorporation of humanitarian and development principles into existing engineering education, as well as dedicated Humanitarian Engineering initiatives, will create engineers equipped to work in complex humanitarian and development contexts. In turn, this will impact in all engineering practice, fostering a generation of engineers able and willing to achieve positive community benefits in all engineering work.

What is Humanitarian Engineering?

Since the early 1980s dedicated organisations utilising engineering to address humanitarian and development challenges have emerged including Engineering for Change (EfC), Engineers Against Poverty (EAP), Engineers for Overseas Development (EOD), Engineers Without Borders (EWB) and Registered Engineers for Disaster Relief (RedR) (UNESCO 2010). These work across the humanitarian spectrum addressing disadvantage, vulnerability and marginalisation, from immediate disaster response, through recovery and stabilisation, to long-term community and infrastructure development, disaster preparedness, and capacity building (Greet 2014). Alongside the growth of these organisations has been the development of education initiatives in the USA, UK and Canada.

In Australasia Humanitarian Engineering is understood as the application of an engineering discipline to a specific humanitarian or development response across the breath of contexts and locations, from disaster response through to community and technology development, both internationally and domestically. Humanitarian Engineering is an area of practice requiring additional dedicated knowledge, skills, and competencies (Greet 2014, Smith et al 2017). All engineering should have its basis in humanitarian objectives, with Humanitarian Engineering specifically engaging disadvantaged, marginalized or vulnerable communities by actively addressing and prioritising in engineering practice.

Humanitarian Engineering in Australasia

A small number of not-for-profit organisations have led the development of education and training. RedR Australia was established in 1992 to make engineering available to disaster relief and has expanded to offer expertise across all aspects of humanitarian emergencies (excluding medical). RedR Australia provides training courses for professionals and more recently to students through university partnerships.

The first wide-scale offerings were developed by Engineers Without Borders Australia (EWB-A), established as an independent national organisation in 2003 with a focus on community development in Australia and the surrounding region. EWB-A delivers three tertiary education programs, the EWB Challenge, Undergraduate Research Program and Humanitarian Design Summits. EWB New Zealand (EWB-NZ), established in 2008, provides three similar opportunities to NZ universities. Since 2016, further opportunities have commenced including Australia chapters of Engineering World Health (EWH), Unbound (formerly Laika Academy) and Project Everest. These provide experiences across allied topics including design for social change, sustainable development, health service delivery, social enterprise and community rebuilding.

University Offerings

Since 2016 several universities have launched diplomas, majors and minors. Dedicated elective courses are available at least six institutions with these and others proposing a range of new courses and programs within the next two years (a full list of these can be found in Smith et al 2017). Approximately 60% of the universities that offer engineering in Australasia are involved in some form of Humanitarian Engineering with an estimated 9,500 students engaged in 2017 through programs such as the EWB Challenge and EWB Design Summits.

Why introduce Humanitarian Engineering Education?

Humanitarian Engineering education produces engineers with discipline depth supported by professional breath. Through a broader range of experiences such as stakeholder engagement, cross-cultural immersion and working in complex socio-technical systems, graduates are better equipped to support community aspirations, achieve empowerment through technology, and develop robust and creative engineering in all their practice.

There is evidence of greater female participation in Humanitarian Engineering with current initiatives reporting 50-100% higher female engagement. This could encourage female students to study engineering and increase the current level of about 15%, leading to greater diversity in Australia's future engineering workforce. This leads to a profession with greater emotional intelligence and societal awareness, able to realise Engineers Australia's 2017/18 – 2019/2020 Strategic Plan's new purpose "Engineers Australia shapes the future of Australia – creating happy, healthy, prosperous and sustainable communities". Humanitarian Engineering will play a vital role in achieving this vision and ensuring all communities domestically and internationally have access to engineering and the positive benefits it brings.

Challenges

Humanitarian contexts are highly complex and multi-disciplinary, often involving engagement with vulnerable and at risk individuals and communities requiring the highest level of ethical practice and safe conduct. Time must be committed to developing long-term relationships to support collaborative decision making and ensure outcomes are generated for all parties. Support must be provided to academics to allow for the required planning and engagement, as well as acquisition of new skills and relevant experience. Education opportunities must be able to extend beyond short-term academic delivery cycles.

The cost of participation in activities such as immersive study experiences, which are critical for student learning, can be prohibitive. The Federal Government's New Colombo Plan (NCP) has provided scholarships and eased the costs but these are only available to domestic students, may still leave a funding gap, and are not necessarily ongoing.

The way ahead

There is a need to professionalise Humanitarian Engineering to ensure appropriate practice and trust for the students and communities involved and the public at large. In 2017 the Humanitarian Engineering Education Network of Australasia (HEENA) was established by universities and organisations in the area to support and encourage continued growth.

HEENA has identified the priorities below to foster student outcomes and academic excellence, and achieve positive impacts for communities and individuals in Australasia and overseas.

Expand and provide appropriate support, recognition and CPD for staff to deliver programs utilising safe, ethical and appropriate humanitarian practices. Academic fellow roles on EWB Summits are available to provide staff with experience of humanitarian practice. Capacity is being built through EWB Challenge academic workshops, new dedicated academic positions, and expertise provided by HEENA, EWB-A and RedR. Staff recognition and support must capture the long-term and complex nature of the engagements and programs involved.

A shared understanding of Humanitarian Engineering, its competencies and its application to enable appropriate delivery of education, research and impact. In professionalising the sector, Australasia can demonstrate international leadership in the area.

Establish a national advisory board to provide guidance, advocacy and engagement across stakeholders. Under this, HEENA will continue to work with a broad range of organisations to develop shared resources, training, support and understanding of practice. Opportunities for funding for staff development, student opportunities and community benefit, should be identified and championed.

Portray engineering in a new light with EA, as a profession able and willing to meet 21st Century challenges and achieve positive and sustainable benefits for communities. Engineering Faculties should consider implementing award programs or part thereof on Humanitarian Engineering, which has the potential to attract greater diversity of students, including higher female participation, to create an inclusive engineering profession.

References

1. UNESCO (2010). Engineering: issues, challenges and opportunities for development. *UNESCO Publishing.*
2. Greet, N. (2014). Building a humanitarian engineering network – A collaborative challenge. *Collaborative Outcomes Pty Ltd Australia*
3. Smith J et al (2017). The Rise of Humanitarian Engineering Education in Australasia. Proc AAEE2017 conference, Manly, Australia.

Australian Council of Engineering Deans Inc.
The membership of the Inc. (ACED) is a senior academic representative of each of the 35 Australian universities that provide professional engineering degrees accredited by Engineers Australia. ACED's mission is to promote and advance engineering education, research and scholarship on behalf of the Australian higher education system.
Contact: Prof Doug Hargreaves AM. ACED Executive Officer. d.hargreaves@qut.edu.au