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.

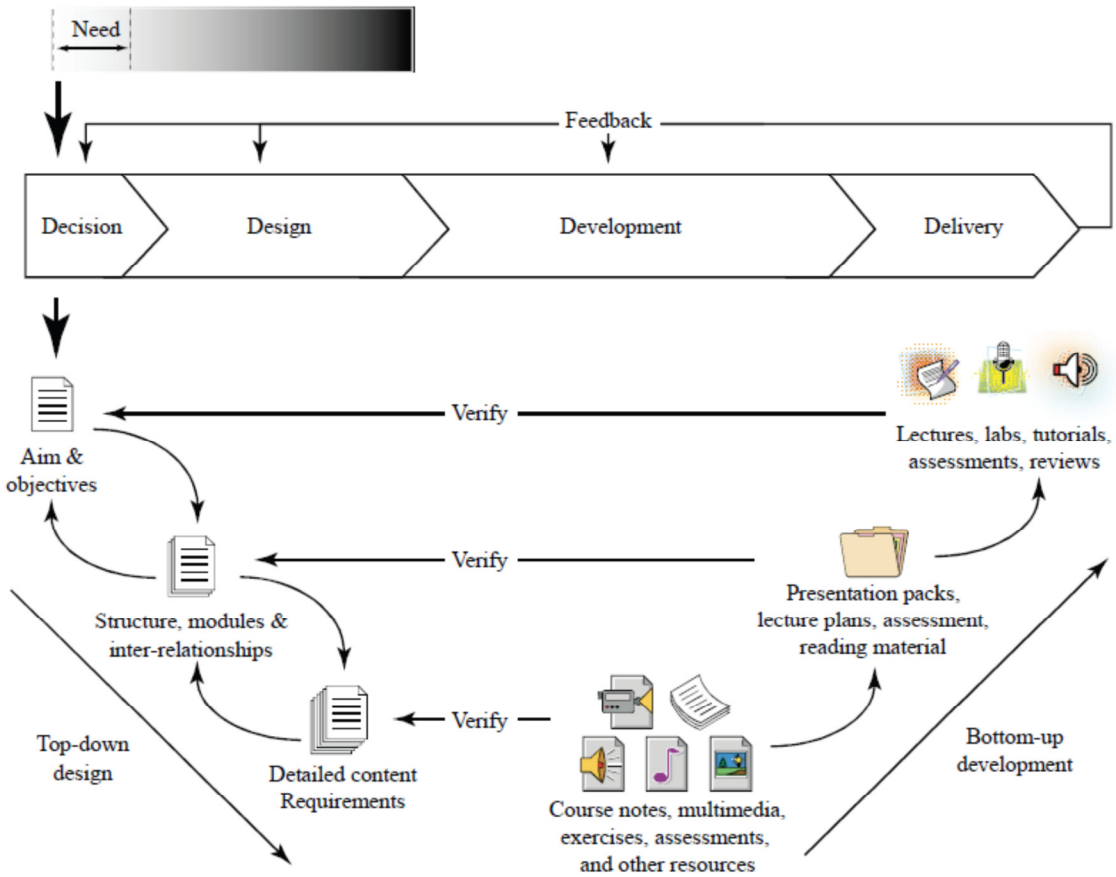

Figure 1: Curriculum development approach (from Faulconbridge and Dowling, 2010)

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 Adaptation

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.

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