Creating International Experiences for First-Year Engineers Through the EWB Australia Challenge Project

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ABSTRACT

The Engineers Without Borders (EWB) Challenge is a design program for first year engineering undergraduates who work in teams to develop conceptual designs for projects identified by EWB partners in developing countries. The identified project briefs are introduced within existing technical areas of the curriculum and contribute towards the sustainable development of disadvantaged communities in developing countries. The project briefs are designed to educate and familiarize engineering undergraduates and academics in key 21st century issues including globalization, climate change, sustainability and poverty alleviation - the "Global Dimensions" (Bourn & Neal, 2008). The EWB Challenge aims to develop more holistic global skills in engineering undergraduates, expanding their critical thinking, multi-disciplinary team working, ability to work across cultures and contexts, systems thinking and communication skills to ensure that they are better equipped to address future global engineering challenges.

The EWB Challenge has been piloted at Colorado State University over the last two years as part of a first year general engineering design class. This paper reports on the implementation, the feedback and reflections from students over the two years. Students reflected that in general, the EWB Challenge had facilitated a good introduction to engineering, global and cultural influences along with professional skills and had directly helped them improve their skills in these key areas. Finally, the paper's authors reflect on improvements to their implementation at Colorado State University going forward and suggest different options for other universities to include the EWB Challenge as part of their curriculum.

INTRODUCTION

Motivation

At Colorado State University ENGR 101 is offered for entering engineering students who have not chosen a major from the currently eight options available. For students who have chosen a major the departments provide a two-course sequence of introductory courses for their respective programs. To assist students still making a decision about a major ENGR 101 was developed around the National Academy of Engineers Grand Challenges (www.engineeringchallenges.org). There are several goals for this course including developing an understanding of the major challenges faced by society as articulated in the Grand Challenges, exposing students to the available majors in the college, and developing students' abilities in some basic engineering skills, e.g. computing. An underlying philosophy of ENGR 101 is that engineers need to be as actively engaged in problem definition as they are in problem solving. Most of engineering curricula focuses on problem solving so this course is designed to try to get students thinking about problem definition at this early stage of their academic careers.

In the fall semesters of 2014 and 2015 the decision was made to try engaging the students in a new experience: the Engineers Without Borders Challenge (EWB Challenge). There were several reasons for choosing this project approach for ENGR 101. First, this project provides opportunities for students to see how a problem is defined. The challenge is poorly defined intentionally by EWB Australia, resulting

in the need for students to develop their own problem definitions. Second, the project demonstrates the breath of skills necessary to work in developing areas of the world (Bourn & Neal, 2008). Third, students must work in teams - another basic engineering skill students must acquire (ASEE, 2013). Finally, we feel the exposure to international development is an important aspect of the engineering profession to promote with students. As described next, this approach from EWB Australia differs from the more traditional hands-on build-based projects implemented by EWB USA; which is limited to rather small teams and is, in most cases, non-curricular. Our implementation included two first-year classes with 86 students in 2014 and 153 students in 2015.

Engineers Without Borders Challenge

The EWB Challenge is a design program for first-year engineering students coordinated by Engineers Without Borders (EWB) Australia and delivered in partnership with EWB-UK and EWB-New Zealand. It provides students with the opportunity to learn about design and teamwork communication through real, inspiring and sustainable cross-cultural development projects in one of the following design categories:

- Infrastructure and Construction (2014 & 2015)
- Water Supply, Sanitation, and Hygiene (2014 & 2015)
- Energy (2014 & 2015)
- Waste Management (2014 & 2015)
- Transportation (2014 & 2015)
- Information Communications Technology (ICT) (2014 & 2015)
- Climate Change (2014 & 2015)
- Food Transformation (2015)

The EWB Challenge is part of the wider EWB goal of a transformed engineering sector in that every engineer has the skills, knowledge, experience and attitude to contribute towards sustainable community development and poverty alleviation as well as an understanding of the responsibility of engineers as global citizens (Cook & Howard, 2012). In this way, humanitarian engineering uses a human-centered, strength-based approach to improve community health, wellbeing and opportunity. Each year, the EWB Challenge design brief is based on a set of sustainable development projects identified by the EWB Challenge Development team, based at EWB-Australia, with community-based partner organizations (Mattiussi, 2013). In past years, the EWB Challenge has included developing innovative and sustainable project ideas to support communities in India, Cambodia, East Timor, Nepal, rural Australia and Vietnam.

The program runs within existing university first year engineering classes and can be adapted to fit course duration, engineering disciplines covered and credits awarded, as these, along with the class objectives, are still at the discretion of the administering faculty. Effectively the EWB Challenge provides the context while the university faculty continue to provide the content. This creates a very flexible and appropriate education model that has been used for everything from one-week design crash courses with 1500 students to full semester or year-long design classes (Cook & Howard, 2012).

Engineers Without Borders-Australia founded the EWB Challenge in 2007. Today the EWB Challenge is a mature program imbedded into curriculum at 52 universities in Australia, New Zealand, the UK, Ireland, Malaysia and Dubai, reaching over 10,000 students each year. The EWB Challenge has sparked dialogue amongst academics regarding sustainability education with the program focus of discussion papers at conferences in both Australia and Europe and has been the subject of a collaborative Australian Government Learning and Teaching Council research project grant. (Borrego, Cutler, & Loden, 2010)

IMPLEMENTATION

Class Overview - ENGR 101

To set the stage for this project it is important to provide a brief overview of how ENGR 101 is structured. As mentioned above the class focuses on the NAE Grand Challenges; a list of 14 technological challenges (or solutions) that will dominate engineering in the beginning decades of the 21st century. The approach taken to teaching this class has consisted primarily of a two-step process: first a divergent thinking phase followed by a convergent thinking phase. During the divergent phase, for each challenge the instructors take two or three 50-minute lectures to ask the students to develop ideas of what constitutes each challenge. For example, the challenge of clean water was explored in one class resulting in the ideas shown in Figure 1.

Figure 1 - Sample Idea Generation - Water

Notice the diversity of disciplines represented in the thoughts of first-year engineering students; they brought up politics, ownership, entertainment, habitat, etc. This is the beginning of developing students' problem definition skills. The class is structured to encourage a lot of creative thinking and brainstorming at this stage. It is done in a very interactive manner in class where everyone is encouraged to participate and the role of the instructor is mainly to capture the ideas presented by the students and to encourage broad student participation. The encouraging aspect that has been observed every year has been the much broader thinking from the students than is shown by the narrower, expertise-driven materials provided by the NAE Grand Challenges website.

The convergent phase then entails taking all the ideas collected during the divergent definition phase and making connections between the ideas. The bottom of Figure 1, shows how some of the ideas from class can be clustered under the heading of ‘quality.’ Here categories of issues that are related can be developed. These categories then provide natural opportunities to highlight the various roles of the different engineering majors in working on the challenges.

During the fall 2014 and 2015 semesters, the decision was made to add the EWB Challenge to this course structure. To get started one lecture was dedicated to introducing the project to the students. This introduction was a team effort headed by the first author of this paper. This lecture set the scene for the students by introducing them to the communities in Nepal (2014) and Cameroon (2015) and the design categories. The EWB-CSU student chapter president was also invited to demonstrate the work of their peers at the university and to hopefully interest the students to join the EWB-CSU student chapter in 2014.

Resources

EWB develops multimedia resources in the form of photos and videos, survey data, mapping and other background data to help students gain an understanding of day-to-day life in the community where the EWB Challenge is set and gain an appreciation for the cultural and social context. These resources are published and disseminated on the EWB Challenge website www.ewbchallenge.org. There are also technical resources, such as water quality data, electrical grid plans, designs/sketches of existing infrastructure etc. are provided where available. In 2015, as the EWB Challenge was located in Cameroon many of the resources were in French to illuminate the difficulties of working in other languages to the mostly English speaking students across the partner countries that undertake the challenge. The students tend to be asked to understand the context and culture that will inform their decisions through individual and team research, having been introduced to the issues through an introductory lecture that includes basic details on the community and their culture including religion, socio-economic, education and language etc. of the community and if applicable, community NGO partner.

However, while the online resources assist students in gaining an understanding of the local context, they are not able to directly interact with the community. With over 7,000 participants in Australia and New Zealand alone this would be too much of a burden on the community partner. In order to simulate this interaction EWB hosts a student discussion forum on the EWB Challenge website where students can post any questions regarding the design projects and local context. These questions are answered by EWB with consultation with the community partner, thus allowing students an avenue to interact with and explore the local context.

Course Integration

One area where the implementation during the first year (2014) of this project fell short in our minds was in how it was integrated into the overall class structure. As described above an active pedagogy is used in the class where students engage in problem definition activities in class and the faculty act as facilitators who encourage the generation of ideas from as many students as possible. For the EWB Challenge, after the presentation was made, the students instead of in-class activities shifted much of the effort to outside-of-class efforts. The effect was the challenge seemed to be an 'add-on' to the class instead of a natural component of a coherent course. After recognizing this mismatch in pedagogical approaches several changes were made to the course in 2015, including: adding a section on engineering design principles, requiring an intermediate submission of project plans from each team, using a peer assessment tool from www.CATME.org to assist students in team work efforts, and hiring a role-playing group to perform a teaming sketch focused on teamwork conflicts and inclusion. In the results section below, the differences between years one and two of the implementation are presented.

We, along with other universities considering using this project, can also take advantage of their student EWB chapters by inviting the students from the group to take part in the class as mentor to the

students or guest speakers who are able to share their experiences of working on engineering projects in other countries.

RESULTS

Survey results

During their final few week of the semester in both 2014 (57 usable responses) and 2015 (108 usable responses), the students were asked to fill in a survey based on their engagement with the EWB Challenge (Table 1).

Table 1: Student reactions to EWB Challenge

2014	2015	Of participating students
47%	41% [1]	now want to join the EWB-CSU Chapter
65%	68%	would like to pursue international opportunities in the field of engineering
68%	81%	recommend keeping the EWB Challenge as part of the course

[1] In 2014, the EWB-CSU chapter presented their project as part of the class, in 2015 this didn't occur

Interestingly, the EWB Challenge (as had been hoped by the faculty) was used by the students to explore engineering and decide or confirm their engineering disciplinary choice. As can be seen in Figure 2 for the 2014 cohort, there was a measurable change within this first semester and the student's choice in discipline. This demonstrates that during the first semester, two thirds (38 students) of the students taking this course changed their engineering field preference, with just under 60% (32 students) of the total students stating that the EWB Challenge experience influenced their current preference.

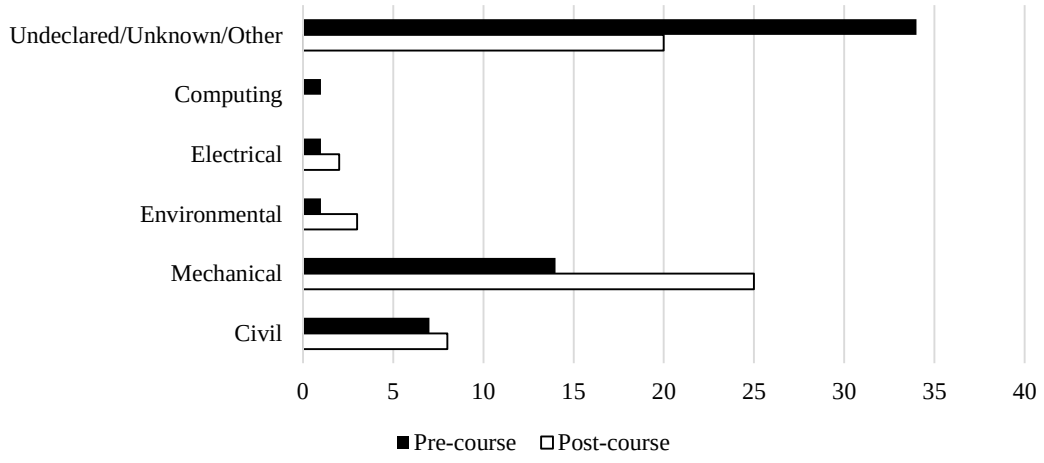

Figure 2 - Engineering discipline choices changes - Fall 2014

Figure 3 presents data from year 2. During this year there was a significant change in the demographics of the class. In addition to this course serving the engineering students who entered without choosing a major, approximately one half of the students entered had already chosen

Mechanical Engineering as their major. This large group of Mechanical Engineering students was enrolled due to lack of space in the Mechanical Engineering department's first year course. In Fall 2015 there were 40 students who changed engineering field during the course and 28 of those recorded that the EWB Challenge influenced their change. It can be seen in Figure 3 that more than half the undeclared/undecided students (23 reduced to 10) used the EWB Challenge to select the engineering field they are interested in studying.

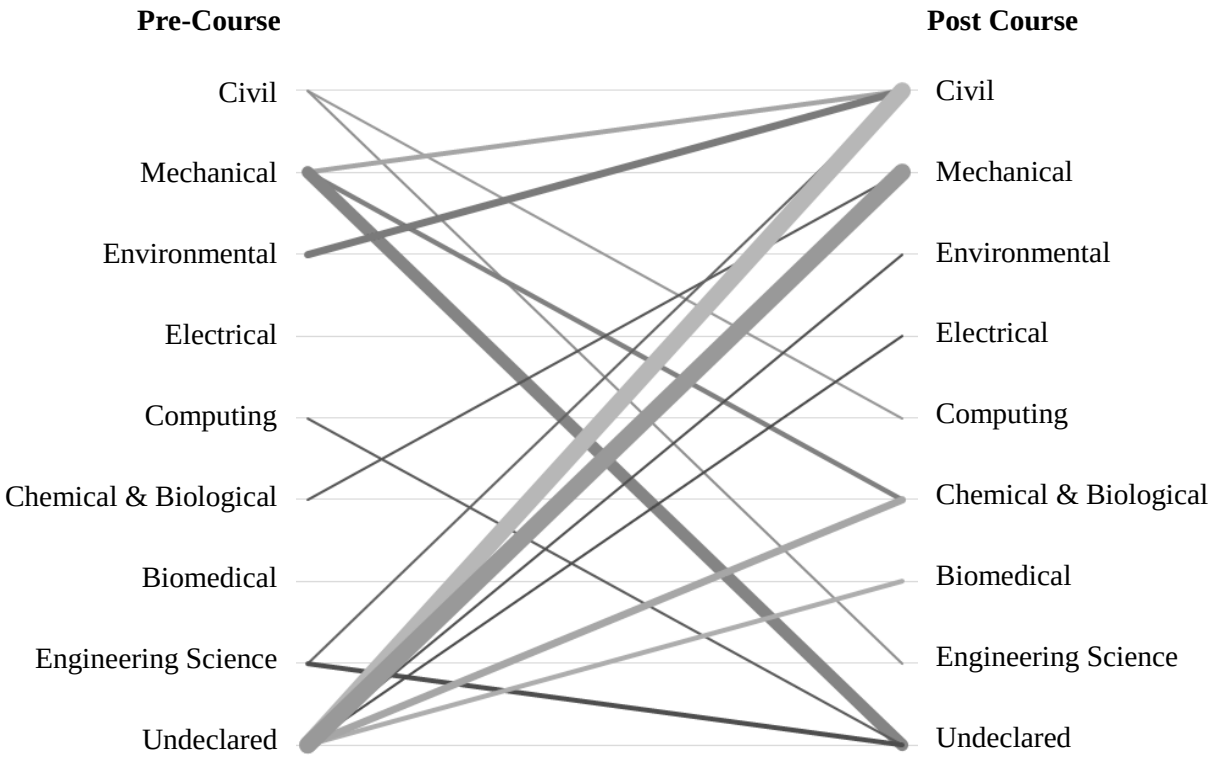

Figure 3: Engineering Discipline Choices Changes - Fall 2015

Students were also surveyed on the change in their understandings of learning outcomes (Figures 4 & 5).

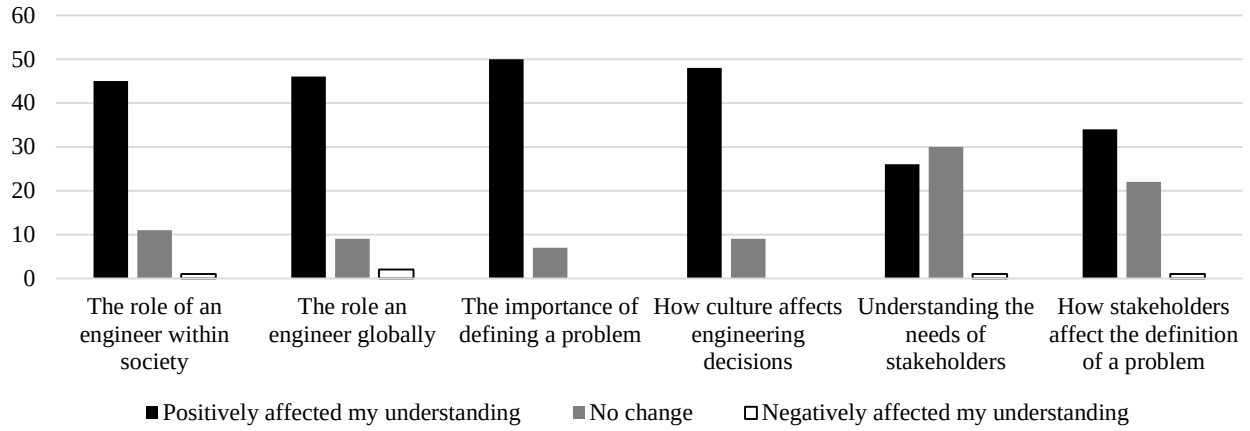

Figure 4 – Answer to the question "How did the EWB Challenge affect your understanding of these issues?" - Fall 2014

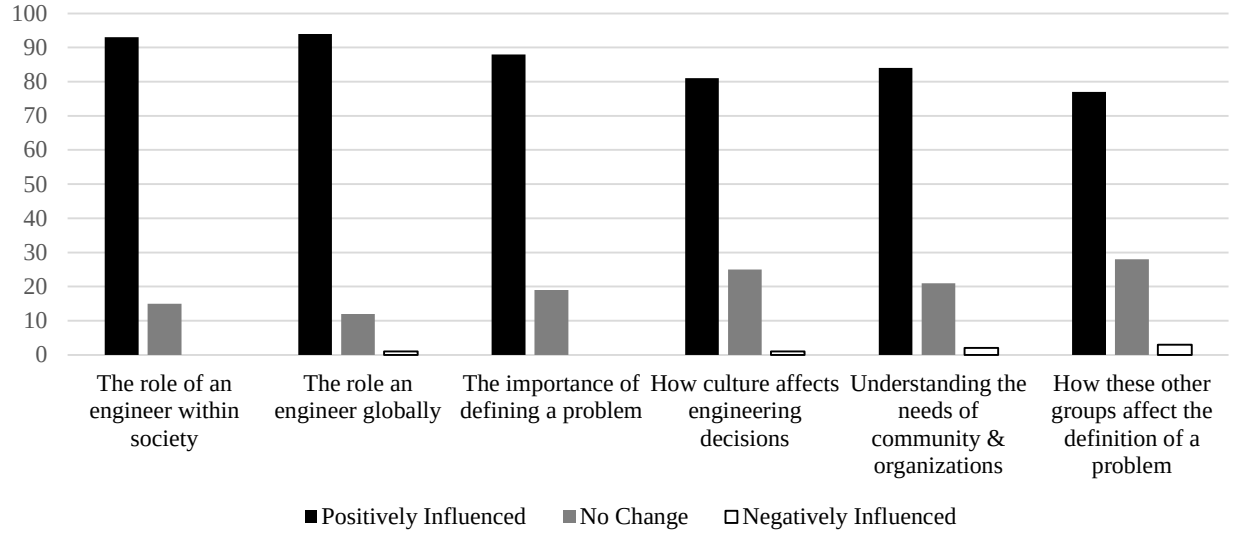

Figure 5 – Answer to the question "How did the EWB Challenge affect your understanding of these issues?" - Fall 2015

As can be clearly seen from the student's self-assessment, students believe they gained a greater understanding around the roles of engineers globally and societally, and the importance of defining the problem and how culture affects decisions. In 2014 there was, from qualitative feedback, a lack of understanding of what stakeholders were, which is demonstrated in the lower levels of comprehension amongst the students in these areas. In 2015 with a clearer understanding of stakeholders as communities and organizations involved or affected by the project student's understanding improved as can be seen in Figure 5.

Students were also asked to self-assess their improvement in professional skills, such as understanding the design process and working in teams and had the EWB Challenge program facilitated this improvement, (Figures 6 & 7).

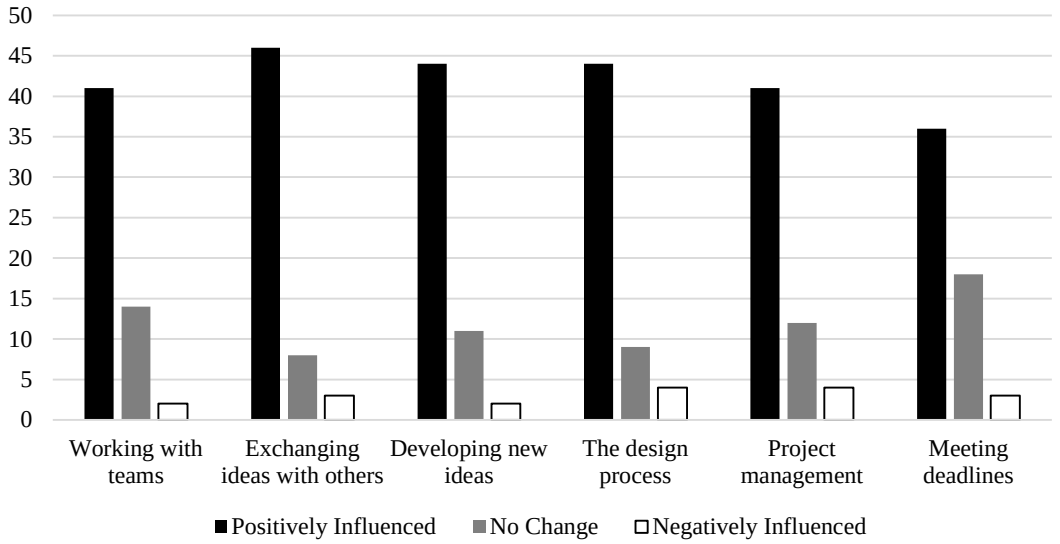

Figure 6: Answer to the question "How did the EWB Challenge affect your personal skills?"- Fall 2014

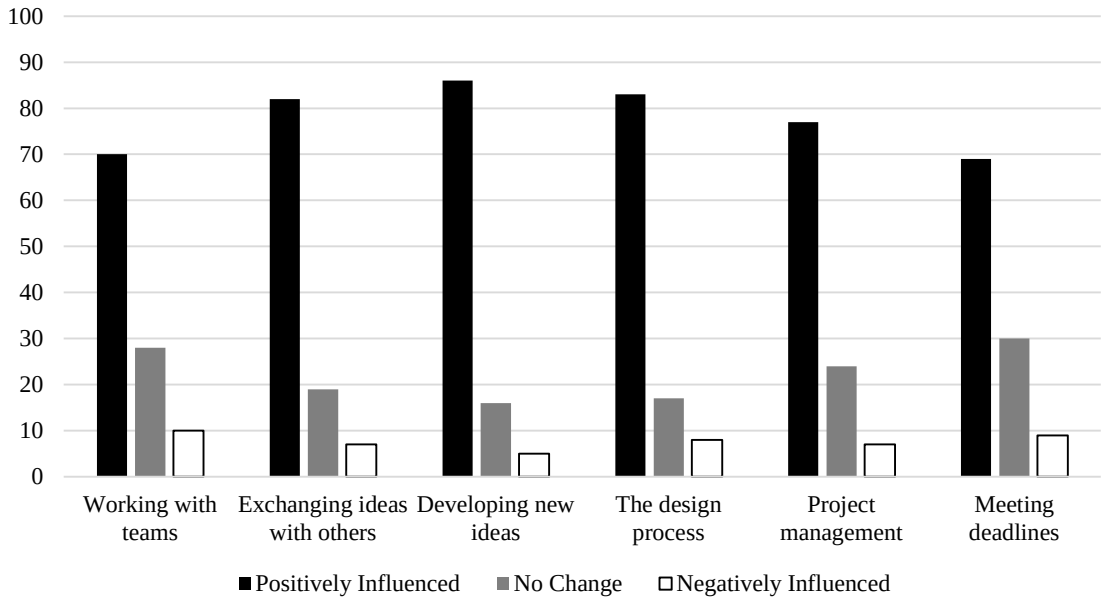

Figure 7: Answer to the question "How did the EWB Challenge affect your personal skills?" - Fall 2015

From this feedback it can be seen that the students, with a few exceptions, felt that the EWB Challenge had acted as a good introduction to engineering and professional skills and had in general helped them improve their skills in these key areas. Through running various analyses on different parts of the results, it was also shown that there was no difference between males and females in their responses to any part of the questionnaire, including on these key understandings and skills.

Finally, the students gave qualitative feedback on the way in which the EWB Challenge was taught at Colorado State University, picking up on some of the same failings in implementation due to the pilot nature of the program but also providing ideas for improvement for future course offerings. A graphic

representation of their feedback shown in Figure 8 below, illustrates the feedback in collated form, with the most repeated words being the largest. It is interesting to see that design, culture, ideas, group, problem(s), learning and working were common themes rather than the technical aspects of the design problems themselves, reflecting on the engagement with professional skills (ASEE, 2013) the instructors hoped would be focused on by the EWB Challenge experience.

Figure 8 - Student Feedback Word Cloud

RECOMMENDATIONS

Others should do this

After the two semesters of experimenting with implementing the EWB Challenge, and reviewing the data collected on the value of this project, the instructors for the ENGR 101 course have come to the conclusion that this is an excellent project to incorporate into first-year engineering courses such as ENGR 101. The challenge is designed for students at this level; students who do not yet have all of the analytical and design skills that are required for the typical on-site EWB-USA projects. This fits very well into the goal of engaging students in project definition activities before embarking on developing solutions. Because the middle years of the engineering curricula tend to focus on developing analytical skills, students do not see many undefined problems at that stage, so this introduction can broaden their understanding of the engineering profession. The EWB Challenge provides valuable engineering background, introduces students to international development issues early in their careers, and connects them to a larger international effort that includes students from all over the world.

The students at Colorado State University seem to have become more interested in being active in international efforts such as EWB projects so the EWB Challenge can be used as a complement to the existing EWB-USA efforts. The Challenge also engages many more students than the on-site projects can without the associated travel and building costs of a development field project. In other words it is a lower threshold introduction to international development engineering. At the same time, many of the

challenges in this project also naturally connect to the NAE Challenges, showing the students that these are truly global issues.

This leads to our first recommendation: schools in the US should consider joining this international design effort. The percentage of engineering students studying abroad, or working and traveling abroad for projects such as EWB-USA is very low and the EWB Challenge provides a good, low cost entry point.

We should do it better

A second recommendation and a lesson learnt from the implementation of the EWB Challenge Colorado State University, is the need to fully integrate this project into the course. As mentioned earlier during the first implementation of the challenge, it effectively operated as an add-on to the existing course. In the second offering more thought was put into making the challenge an integral part of the course. This included efforts to more fully integrate the challenge into the class time divergent/convergent activities. This resulted in a more active pedagogy for the project. The instructors also recognize that even though the EWB Challenge is aimed at this level of student, they needed to provide better support for the students. Specifically in the second offering extra content was added to assist in developing their teamwork skills required for this effort along with formal instruction on engineering design processes and principles. It also became clear that the project should be introduced earlier in the year as this would allow for better support and provide more time to have in-class presentations.

Other Approaches

The EWB Challenge, as previously mentioned, started in Australia in 2007 and is now undertaken by approximately 90% of engineering undergraduate students in Australia. It is supported by a staff and volunteer team in Australia who provide the resources and support universities and faculty by creating learning opportunities for faculty, acting as an additional resource for the faculty and providing the launch lecture. This approach was replicated in the United Kingdom when the program was first implemented there in 2011 and the support from the local NGO, Engineers Without Borders UK has scaled as the program has grown (Cook & Howard, 2012; Mattiussi, 2013). In Australia and the UK there are also many curricular models that take the ideas of working in multi-disciplinary teams and peer learning further, which have been used to great success at universities in the UK and Australia. At the University of Sheffield, UK, the university cancels all classes across all of engineering (approximately 1200 students) for a design week, where they come together in multi-disciplinary teams, mentored by trained graduate assistants to replicate real world working conditions. At Imperial College London, UK, the EWB Challenge is one option in mandatory cross-campus team based classes. In this weekly, three-hour block students from across the Colleges of Engineering, Medicine, Natural Sciences and Business (and all three years of the bachelor degree programs) come together to work together on truly multi-disciplinary and multi-level teams in this peer-led learning environment. This flexibility allows the EWB Challenge to become part of almost any variation on a group design project based class. (Mattiussi, 2013)

Currently, the resources to run the EWB Challenge are available for free and open source from the project website and universities are welcome to download and use these in their own classes. Limited support may also be available from the staff and volunteer team at EWB Australia, EWB-UK and the faculty and students at Colorado State University.

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