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The EWB Challenge – Preparing engineers to work globally through international development design projects

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The EWB Challenge – Preparing Engineers to Work Globally Through International Development Design Projects

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Abstract

Since 2014 Colorado State University College of Engineering has been involved with the first United States based pilot of the Engineers Without Borders Australia global design challenge (EWB Challenge). The EWB Challenge is a series of design challenges in different technical areas, created in cooperation with a local community and non-government organization in a different development setting and location each year. Challenges in previous years have been based in Vietnam, Nepal, Timor Leste, Cameroon, and India in partnership with Non-Government Organizations (NGO's) such as the Nepal Water for Health and Habit for Humanity. The EWB Challenge utilized in the design class this year at Colorado State University was based in the Mayukwayukwa refugee settlement in Zambia, partnered with the United Nations Refugee Agency. The EWB Challenge has been developed to be flexible for multi-disciplinary, intra-disciplinary or single discipline engineering design courses in the first and second year of undergraduate engineering degrees. The EWB Challenge program has been embedded into the curriculum of over fifty universities in Australia, New Zealand, the United Kingdom, and the Republic of Ireland.

This paper reports on the change in 118 first year civil and environmental engineering student's global preparedness attributable to their taking a one semester, first-year civil engineering design class in which the EWB Challenge is taught at Colorado State University. The change has been measured utilizing the validated Engineering Global Preparedness Index (EGPI) as a pre-test and post-test (with retrospective pre-test to account for response shift bias). The EGPI instrument measures the students self-identified changes regarding engineering ethics, efficacy, global-centrism and community connectedness. Students responses have been compared through segmentation, to understand how gender, age, previous international travel, or involvement with student organizations such as the university's Engineers Without Borders USA student chapter affect student's self-efficacy responses.

Index Terms – Global Preparedness, Design Project, International Development, EWB Challenge

Introduction

The United Nations Sustainable Development Goals (SDGs) [1] require engineers who are defined by their intersectionality, that is, engineers who are technically competent in their field(s) of engineering but also have the global and professional skills to be able to practice engineering outside their native context and culture.

However, there are two significant barriers to fulfilling this need. First, there are not enough engineers being trained worldwide, particularly in developing countries [2]. Second, engineering students who do graduate are often not prepared with the skills and competencies needed to work in a global workplace. Skills such as communication, ethics, and cultural and global adaptability are needed to prepare engineering graduates to work on transnational teams in differing regulatory and socio-economic realities in different country and local contexts [3]. The United Nations Educational, Scientific and Cultural Organization (UNESCO) report 'Engineering: Issues, Challenges, and Opportunities for Development' report [4] suggest the model in Figure 1, which re-centers engineering in a systematic model which moves away from engineering design as a scientific/technologically focused vocation. The proposed model reconnects engineering to its role in providing products and benefits that fulfill the needs of society and nature using technology and scientific theories.

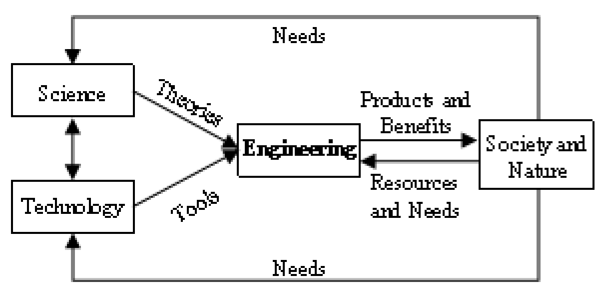

FIGURE 1
ENGINEERING SYSTEM MODEL – ADAPTED FROM UNESCO [4]

This model suggests the need for engineering design classes in engineering colleges that teach students how to understand and respond to the global needs of society and nature through the use of engineering theories and tools.

GLOBAL PREPAREDNESS

Global Preparedness is defined by Ragusa [5] as engineering student's preparedness for global workplaces and is measured by competency in communication, professional ethical responsibility, understanding of global issues and lifelong learning. It is theoretically grounded in the development of Zeichner's [6] global citizenry theory.

There has been a significant level of research activity around the concept of globally competent engineers and as part of exploring the rationale for preparing engineering students for the global workplace [7]. In engineering, global engineering competency can be seen as inhabiting three dimensions of technical, professional, and global domains, which contain the skills and attributes of a globally competent, professional engineer[8]. Brigham-Young University's Mechanical Engineering Department worked with their alumni in 48 states and 17 countries to develop their set of global competencies [9]. Drawing on this previous work, the American Society of Engineering Education's Special Interest Group on International Engineering Education collaborated with the International Federation of Engineering Education Societies (IFEES) and the Global Engineering Dean's Council (GEDC) to develop and implement a survey instrument to validate the attributes they saw as essential to a globally competent engineer [10]. Table 1 synthesizes the findings from these different research projects to demonstrate the necessary skills and attributes within the global domain, for the globally competent engineer.

TABLE 1
SYNTHESIS OF THE GLOBAL ATTRIBUTES OF A GLOBALLY COMPETENT ENGINEER

SKILLS & ATTRIBUTES OF THE GLOBALLY COMPETENT ENGINEER	ALLERT [8]	PARKINSON [7]	GREGG [9]	HUNTLEY [10]
Work effectively in diverse & multicultural global environments	X	X	X	X
Language	X	X	X	X
World/global affairs & policies	X	X	X	
International relations	X		X	X
Global citizenship	X	X	X	X
Global product platforms	X	X		
Economics/outsourcing	X	X		X
Socio/political impact on problem definition	X	X		X
Appreciate cultural value differences.	X	X	X	X

It can be suggested that these skills and attributes can be gained through engineering design courses in universities, if the context of the project is explicitly and deliberately global, to provide students with the opportunity to understand engineering design as an appropriate response to the cultural and contextual realities of their clients.

THE EWB CHALLENGE PROGRAM

The Engineers Without Borders (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 toward sustainable community development and poverty alleviation as well as an understanding of the responsibility of engineers as global citizens [11]. In this way, humanitarian engineering uses a human-centered approach to improving community health, wellbeing and opportunity. Each year, the EWB Challenge design brief is based on a set of sustainable development projects identified by EWB-Australia, with community-based partner organizations [12]. In past years, the EWB Challenge has included developing innovative and sustainable project ideas to support communities in India, Cameroon, Zambia, 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 continues to provide the content. The methods used 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 [11]. Engineers Without Borders-Australia founded the EWB Challenge in 2007. Today the EWB Challenge is a sophisticated program embedded into the curriculum at 52 universities in Australia, New Zealand, the United Kingdom, 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. [13]

In the year studied, the EWB Challenge allowed students to co-create engineering solutions and management strategies to challenges faced by the community living in the Mayukwayukwa refugee settlement in the Kaoma District of Zambia's Western Province. The project partnered with a local NGO supporting the communities transition to a permanent settlement the UN (United Nations) Refugee Agency (Zambia). The EWB Challenge has been piloted at Colorado State University for the past two years and was investigated as part of a previous study [14].

STUDY DESIGN

To understand the students understanding of their change in global preparedness through the EWB Challenge project, the students were asked to undertake the Engineering Global Preparedness Index [5, 15, 16] quantitative questionnaire at the start and end of the semester-long first year civil and environmental engineering design course in which the EWB Challenge was taught.

Engineering Global Preparedness Index Questionnaire

The Engineering Global Preparedness Index (EGPI) instrument was developed as part of a multi-university effort to develop a quantitative measure to study engineering students preparedness for global workplaces, having discovered that no such measure existed [5]. The instrument was created to identify the effect of formal and informal education practices and interventions on student's global preparedness and was developed to align with both the National Academy of Engineering 'Engineers for 2020' publication [17, 18] and the ABET standards [19]. The instrument is built of four subscales and forty-one items, outlined in Table 2, all of which are measured on a five-point Likert scale.

TABLE 2
EGPI SAMPLE ITEMS BY SELECTED SUBSCALES [15]

SUBSCALE/CONSTRUCT	SAMPLE INDEX ITEM
Global Engineering Efficacy	I believe that my personal decisions and the way that I implement them in my work activities can affect the welfare of others and what happens on a global level.
Engineering Ethics & Humanitarian Values	Engineers in my country have a moral obligation to share their engineering knowledge with the less fortunate people of the world.
Engineering Global-centrism	I think my country needs to do more to promote the welfare of different racial and ethnic groups in engineering industries.
Engineering Community Connectedness	To treat everyone fairly, we need to ignore the color of people's skin in our workplaces

The instrument contains sections focusing on engineering professional skills and student experiences regarding technology, news, and other societal engagement factors. Finally, the instrument asks the participants for their age, gender, racial/ethnic background, generational citizenship, current engineering major as well as if they have lived, done community service, or studied abroad. One question was added to the instrument for this study, to ask participants if they have or are involved with Engineers Without Borders USA or another international engineering service organization.

Issues with Response Shift Bias

Most qualitative measures of global preparedness or awareness are by nature, self-efficacy, which may call into question the level of ability of students to self-assess given their respective levels of experience. As an example, a recent study into the EWB-USA chapter at University of Colorado, Boulder found that members of their student chapter perceived (through self-efficacy surveys based on the ABET criteria) to have less technical skills than their peers that haven't been involved in the chapter, but greater broad and holistic skills such as ethics, management, finance and communication [20]. The authors suggest that this is due to the contexts and 'real world' application of skills that the EWB chapter members have experienced, compared with their peers who may not have applied their learning non-academically.

This also demonstrates the issue of response shift bias within intervention models [21] whereby the intervention causes the participants to re-evaluate the basis of their pre self-evaluation. With a pre-test/post-test evaluation model, participants will shift their responses on the post questionnaire based on the new knowledge or levels they have developed through the intervention, without having the opportunity to amend their pre-responses, which often uncovers pre-test overestimation [22]. Adding a retrospective pre-test to the post-test allows participants to self-evaluate their change through the intervention, which if a pre-test was also performed, can be used to check and shift their initial responses to match the participant's post-intervention levels [23]. There are however some issues with using retrospective pre-tests, namely that it can increase participants desire to show change and they introduce threats to validity such as memory recall, history, and regression towards the mean [24]. Within this study, the EGPI instrument is used as both a pre-test and as a combined post-test and retrospective pre-test to account for response shift bias.

Data Collection

All students in the civil and environmental engineering CIVE103 Engineering Graphics and Computing course (this course acts as one of a pair with CIVE102 to introduce students to Civil and Environmental Engineering) were also asked to take the EGPI Questionnaire at the beginning of the semester in January 2017, during their lab classes associated with the course. These lab classes are held in a computer lab and so the questionnaire, and IRB consent form was given online in Qualtrics. Of the 180 students present in the six lab class sections, all students consented to and took the questionnaire. The questionnaire was repeated near the end of the semester in April 2017 as a combined post-test and retrospective pre-test. Of the 175 students present in the six lab class sections, 167 students (95.5%) consented to and took the post-test and retrospective pre-test questionnaire, full details of declared major and gender demographics are reported in Table 3, resulting in, after data cleaning, 118 (64.5%) complete sets of responses.

TABLE 3
DEMOGRAPHICS OF STUDENTS IN CIV103 COURSE

STUDENTS WHO	Pre-test no.	Post-test no.	Complete Data Sets no.	Complete Data Sets* %
Self-Identified as Female	60	57	44	37
Self-Identified as Male	120	110	74	63
Majoring in Civil Engineering	132	121	88	76
Majoring in Environmental Engineering	47	41	28	22.5
Yet to declare a major	1	5	2	1.5
TOTAL	180	167	118	64.5

* This is the number of students who provided a complete data set, after the data was cleaned and responses with missing data removed.

STUDY RESULTS

Instrument Subscale Validation

Principal axis factor analysis with varimax rotation was conducted to assess the underlying structure of the forty-one item global preparedness portion of the EGPI instrument and to confirm the validity of the four subscales within the instrument design. Firstly, assumptions were tested and demonstrated through the Bartlett test and correlation determinant that all three tests were correlated highly enough to provide factors but that collinearity within the data would not be an issue. The Kaiser-Meyer-Olkin measures for each test were greater than 0.7, demonstrating that there would be enough items predicted by the four factors to validate the sub-scales and the percentage of variance accounted for by each subscale with each of the three tests is outlined in Table 4.

TABLE 4
PERCENTAGE OF VARIANCE ACCOUNTABLE TO EACH SUBSCALE WITHIN THE THREE TESTS

SUBSCALE WITHIN THE INSTRUMENT	AMOUNT OF VARIANCE ACCOUNTABLE %		
	Pre-test	Retrospective Pre-test	Post-test
Engineering Efficacy	12.17	16.64	15.42
Engineering Ethics	10.45	11.76	11.32
Engineering Global-centrism	5.40	5.02	6.94
Engineering Community Connectedness	4.45	4.33	3.99
TOTAL	33.02	37.76	37.67

After determining the four subscales to be valid within this data, Cronbach's alpha's were computed to assess if the data from the items in each subscale is reliable. The alpha for the twenty-five items included in the Engineering Efficacy subscale was an average across the three tests of 0.89. Similarly, across the three tests, the average alpha score for the twenty-two items within the engineering ethics subscale was 0.84. The average alpha across the three tests for the sixteen items in Engineering Global-centrism subscale was 0.77; these three subscales have good internal consistency reliability. Finally, the Engineering Community Connectedness subscale consisted of thirteen items. However, the alpha score of 0.69 only indicated minimally adequate reliability.

Response Shift Bias

The student's responses clearly demonstrated the issues of response shift bias as can be seen in Table 5. The students mean response dropped by 0.22 between their pre-test responses and their retrospective pre-test responses demonstrating that they gained a greater understanding of the question and their relative response level through the period of the course. The importance of this is demonstrated by the comparable difference between the post-test mean scores for the four subscales and the pre-test/retrospective pre-test responses. Comparing the students mean post-test responses against their pre-test responses would have resulted in a drop across all four sub-scales. By comparing their retrospective pre-test responses, positive change is seen instead across all four subscales however within the sub-scales, sixteen of the forty-one items did not demonstrate a significant ($p < 0.05$) change.

TABLE 5
MEAN & STANDARD DEVIATIONS OF STUDENT RESPONSES TO TESTS

SUBSCALE WITHIN THE INSTRUMENT	PRE-TEST		RETROSPECT. PRE-TEST		POST-TEST	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
Engineering Efficacy	4.08	.86	3.86	.98	4.02	0.97
Engineering Ethics	3.84	.94	3.59	1.06	3.71	1.08
Engineering Global-centrism	3.94	.92	3.72	1.01	3.87	1.03
Engineering Community Connectedness	4.02	0.93	3.84	1.02	4.00	1.01

Global Engineering Efficacy Sub-scale results

A paired samples *t*-test indicated that of the twenty-five items defined as part of the subscale by the factor analysis, seventeen demonstrated a significant increase between retrospective pre-test and post-test responses. On average, the student's responses were significantly increased on the post-test on the seventeen items, with mean scores as follows, t (117) = 2.17, p = .12, d = .20. The average difference, although statistically significant is small using Cohen's [25] guidelines, it varies to a maximum of d = 0.51, a medium effect size, on some of the significant items within the subscale.

Engineering Ethics and Humanitarian Values Sub-scale results

Similarly, from the twenty-two items defined as part of the subscale by the factor analysis, a paired samples *t*-test indicated that eighteen items demonstrated a significant increase between retrospective pre-test and post-test responses. On average, the student's responses were significantly increased on the post-test on the eighteen items, with mean scores as follows, t (117) = 1.85, p = .18, d = .17. The average difference, although statistically significant is small using Cohen's [25] guidelines, it varies to a maximum of d = 0.43, a medium effect size, on some of the significant items within the subscale.

Engineering Global-centrism Sub-scale results

For this subscale, a paired samples *t*-test indicated that of the sixteen items defined as part of the subscale by the factor analysis, twelve demonstrated a significant increase between retrospective pre-test and post-test responses. On average, the student's responses were significantly increased on the post-test on the twelve items, with mean scores as follows, t (117) = 2.07, p = .16, d = .19. The average difference, although statistically significant is small using Cohen's [25] guidelines, it varies to a maximum of d = 0.47, a medium effect size, on some of the significant items within the subscale.

Engineering Community Connectedness Sub-scale results

For the final subscale, for the of the thirteen items defined as part of the subscale by the factor analysis, a paired samples *t*-test indicated that nine demonstrated a significant increase between retrospective pre-test and post-test responses. On average, the student's responses were significantly increased on the post-test on the nine items, with mean scores as follows, t (117) = 2.30, p = .02, d = .21. The average difference, although statistically significant is small using Cohen's [25] guidelines, it varies to a maximum of d = 0.29 on some of the significant items within the subscale.

Demographic Differences in Sub-scale results

An independent samples t-test indicates there was no significant gender difference in gain between the retrospective pre-test and post-test on any of the four sub-scales (based on either the full set of items or reduced sets, defined as the significant items found through the paired samples *t*-test). However, deeper investigation shows that there is a significant difference on individual items within the instrument.

There is also a significant difference between genders in the level of response to the four subscales as shown in Table 6 (at a significance level p = 0.1). Female students had significantly higher scores on the post-test questionnaire than the male students. While the Engineering Community Connectedness subscale has a large effect size d of 1.49, based on Sawilowsky's [26] expansion of Cohen's [25] effect sizes, the effect size d of over 2.0 for the other three subscales demonstrates the huge effect of gender on the differences in responses.

TABLE 6
COMPARISON OF FEMALE AND MALE POST-TEST RESPONSES BY SUB-SCALE (N= 44 FEMALES & 77 MALES)

SUBSCALE	*M*	*SD*	*t*	*df*	*p*	*d*
Engineering Efficacy			3.18	116	.02	2.19
Female	105.30	11.53				
Male	97.53	13.57				
Engineering Ethics			.410	116	<.01	2.56
Female	79.32	8.82				
Male	71.23	11.17				
Engineering Global-centrism			4.01	116	<.01	2.19
Female	61.91	7.77				
Male	55.70	8.33				
Engineering Community Connectedness			3.06	116	.03	1.49
Female	54.41	5.98				
Male	50.66	6.69				

While this class is traditionally taken by most students in their second semester of their first year in engineering, there are a number (n = 13) of non-traditionally aged students, who by the end of the course were 21 or older. There was a significant difference in the gain on the Engineering Global-centrism subscale as is shown in Table 7.

While this experience did not seem to provide a similar gain for non-traditionally aged students as it did for traditionally aged students, on Engineering Global-centrism it has created a drop in self-efficacy levels. There were no significant differences between traditionally aged and non-traditionally aged students on the post-test responses across all four sub-scales.

TABLE 7
COMPARISON OF TRADITIONAL AND NON TRADITIONALLY AGED STUDENT RESPONSES BY SUB-SCALE (N= 13 STUDENTS OVER 21 & 105 STUDENTS 18-20)

SUBSCALE	*M*	*SD*	*t*	*df*	*p*	*d*
Engineering Efficacy			1.90	116	0.60	1.28
Over 21 yrs' old	.00	3.49				
18-20 yrs' old	2.59	4.76				
Engineering Ethics			.72	116	.47	.53
Over 21 yrs' old	.84	2.73				
18-20 yrs' old	1.91	5.18				
Engineering Global-centrism			4.49*	32.25*	<.01*	1.44
Over 21 yrs' old	-.54	1.33				
18-20 yrs' old	1.61	3.12				
Engineering Community Connectedness			1.28	116	.20	.60
Over 21 yrs' old	0.38	1.45				
18-20 yrs' old	1.2	2.24				

* The *t* and *df* were adjusted as the variances were not equal.

There was no significant difference in gain on any of the four subscales between students who had lived, done community service, or studied abroad in another country and students who had not. There was as shown in Table 8, significant difference levels of response on three of the subscales, students who had lived, done community service or studied abroad demonstrated higher levels of engineering efficacy, Global-centrism, and community connectedness. Sawilowsky's [26] effect sizes show a huge effect size ($p = 2.21$) for engineering efficacy and a very large effect size ($p > 1.2$) for the remaining two scale items. This demonstrates that students who have traveled find it much easier to connect engineering to global contexts and to understand the interconnected nature of engineering globally.

TABLE 8
COMPARISON OF STUDENTS WITH AND WITHOUT PREVIOUS INTERNATIONAL EXPERIENCE BASED ON POST-TEST RESPONSES BY SUB-SCALE
(N= 38 WITH PREVIOUS EXPERIENCE & 80 WITHOUT)

SUBSCALE	*M*	*SD*	*t*	*df*	*p*	*d*
Engineering Efficacy			3.09	116	<.01	2.21
Experience	105.74	11.89				
No experience	97.90	13.32				
Engineering Ethics			1.59	116	0.11	1.04
Experience	76.58	11.03				
No experience	73.14	10.93				
Engineering Global-centrism			2.78	116	0.01	1.60
Experience	61.13	8.00				
No experience	56.53	8.57				
Engineering Community Connectedness			2.83	116	0.01	1.41
Experience	54.50	6.60				
No experience	50.90	6.41				

Finally, students were also asked about their previous experience with Engineers Without Borders USA or other international development service organizations. Seventeen students in the class were involved in an international development service organization, and a further seven had undertaken the previous year's EWB Challenge in a different class [27].

There was no significant difference in gain on any of the four sub-scales between students who had had a previous international development experience and students who had not. However, there was, as is shown in Table 9, a significant difference in the post-test student response level of response for the engineering efficacy subscale (at a significance level $p = 0.1$). Students who had had a previous international experience reported higher levels of engineering efficacy and the effect size was huge based on Sawilowsky's [26] effect size scale. There was not a significant difference on the remaining three subscales.

TABLE 9
COMPARISON OF STUDENTS WITH AND WITHOUT PREVIOUS INTERNATIONAL DEVELOPMENT SERVICE EXPERIENCE BASED ON POST-TEST RESPONSES BY SUB-SCALE
(N= 20 WITH PREVIOUS EXPERIENCE & 98 WITHOUT)

SUBSCALE	*M*	*SD*	*t*	*df*	*p*	*d*
Engineering Efficacy			3.70*	56.25*	<.01*	2.40
Experience	106.85	6.91				
No experience	99.11	13.96				
Engineering Ethics			0.94	116	.31*	0.78
Experience	76.35	9.68				
No experience	73.82	11.29				
Engineering Global-centrism			2.38*	55.32*	.12	1.26
Experience	60.75	4.59				
No experience	57.46	9.16				
Engineering Community Connectedness			2.39*	35.77*	.22*	1.28
Experience	54.65	4.94				
No experience	52.53	6.86				

* The *t* and *df* were adjusted as the variances were not equal.

CONCLUSION

The EWB Challenge has a significantly positive impact on undergraduate civil and environmental engineering students' preparedness to understand and work in global engineering. This finding underlines the importance of introducing students to the global context of engineering early in their studies, given the significant difference in gain between traditionally and non-traditionally aged students in this study. As would be expected, students who had had previous experience with international development projects and organizations had a significantly higher post course global engineering efficacy score than students that hadn't had that opportunity. However, all students gained similar levels of efficacy through the EWB Challenge project experience.

Finally, previous studies into the gender differences of engineering identity [28-30] based on Eccles [31] expectancy-value theory have uncovered that generally, female students tend to identify with engineering as a contextualized, human-centered communicative subject [32]. This would suggest female students would be more engaged with projects such as the EWB Challenge which are human-centered and as was found, female students responded at a higher level than the male students to all four subscales of global preparedness. However further work, through analyzing student interviews, is needed to validate and deepen understanding of the changes and differences found through this initial study.

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