AC 2011-2750: ENGINEERING PREPAREDNESS FOR GLOBAL WORKFORCES: CURRICULAR CONNECTIONS AND EXPERIENTIAL IMPACTS

Gisele Ragusa, Ph.D., University of Southern California

Gisele Ragusa is an associate professor in the Viterbi School of Engineering and the Rossier School of Education at the University of Southern California. She has expertise in engineering education, precollege engineering and in assessment and measurement.

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Gisele Ragusa, Ph.D.
University Of Southern California

Abstract

There is a growing concern among universities that students in undergraduate and graduate engineering programs will be unprepared or underprepared to work in global workforces. The National Academy of Engineering (NAE), in their 2005 publication, *Engineers for 2020,* urges university engineering schools nationwide to embed curriculum and assessment measures in their academic programs that provide opportunities and metrics that meet this international challenge. Specifically, the NAE charges universities and colleges to prepare engineers that are leaders with strong globally focused communication, leadership and interdisciplinary research and professional skills in diverse in engineering environments.

This paper describes six universities' response to this important NAE challenge. The paper will describe both curricular and pedagogical research and a measure of engineering global preparedness. In this study, engineering students received interdisciplinary globally focused engineering education and then were assessed as to their preparedness to work in global workforces and research environments. An Engineering Global Preparedness Index was administered to assess this educational and research experience with a summative focus. Results of this metric were compared to students' internationally related pedagogical experiences and precursing international life experiences. Results of this research indicate that engineering students who were most globally prepared also had international experiences in engineering and in other aspects of their life. Additionally, diversity in preparedness per the index was noted, indicating that students with diverse socio-demographic profiles have diverse preparedness indices. In particular, students who were born in nations other than the United States who then received a U.S. based engineering education had high global preparedness.

Introduction

We live in an era with unprecedented changes due to dramatic advances in technology on many fronts. The explosive growth in computing and communication has revolutionized the way we work and live. Increasingly, the engineering work force is becoming more diverse with teams working with global foci. These forces of globalization, demographics, and technological advances are changing the role of engineering in society,[1] identifying a significant problem in the way universities address the engineering profession, engineering education, and associated engineering student assessment processes.

There have been many national studies about critical issues facing universities regarding STEM education, specifically engineering education.[2, 3] With the world becoming "flat" due to globalization, increasingly, jobs requiring basic technical skills are moving outside of U.S. by companies to reduce cost. U.S. engineering graduates must bring higher-level skills including innovation, a problem solving approach, and leadership to their workplace. There are recent reforms in engineering education as efforts to meet the changing needs of engineers nationally and globally, however sparse research exists that comprehensively assesses the outcomes associated with such engineering education reform efforts.

Traditionally, engineering education involves deductive instruction and associated assessment in which the faculty lecture on general principles with limited application of the principles to real life engineering situations, real life situations, and simulations and simply test students on their lecture materials. Deductive instructional approaches and static assessment have significant limits in preparing engineers for a changing global society and measuring this preparedness as required by National Academy of Engineering (NAE).[2,4] The necessity for engineering education reform requires radically new, innovative and closely aligned curricular and assessment approaches. Such approaches must solve important engineering problems[5] and measure preparedness for global impact.

Global Preparedness

While science, technology, engineering, and mathematics (STEM) graduate programs in the U.S. are dominated by international students (foreign students made up 47% of all graduate enrollments in engineering in the U.S.), other countries are outpacing the U.S. in producing scientists and engineers. Importantly, of all undergraduate degrees awarded worldwide in science and engineering in 2009, 72 % were awarded outside the United States. Similarly, of all doctoral degrees earned worldwide in science and engineering, 78% were earned outside the United States.[6] Blumenthal and Grothus[7] posit that "engineers need global competencies and multicultural skills as much as any other professionals." Additionally, the NAE[2] requires that engineering students be prepared for global workforces. Engineering schools have great difficulty measuring their students' preparedness for globally focused workforces. Global preparedness cannot be measured with a traditional examination as it involves difficult to measure constructs that fit together as metrics of preparedness. Throughout the past two decades, researchers have attempted to measure related constructs such as citizenry and internationally focused readiness. Unfortunately, none of these metrics exactly aligned to career preparedness in the way that this paper begins to describe. Further, in the recent past, no metrics specifically measure program components that may assist in global preparedness, nor do they focus deliberately on engineering education.

Research Design and Metric Development

After exploring appropriate metrics in engineering education that measure students' preparedness for global workforces and discovering that there were no such metrics with quantitative foci, this research set out to create and test a survey instrument that could measure this important engineering preparatory construct. Precursing this effort, the researcher had been involved with an international research group that was attempting to measure teachers' global citizenry at preservice levels. This group developed an instrument to test the constructs associated with global citizenry for teachers in 2006. Accordingly, the researcher set out to utilize similar constructs associated with the teacher instrument and to adapt the teacher instrument to design an engineering focused measurement of global preparedness. Additionally, the intent was to measure the impact that formal and informal practices on engineering global preparedness. After much development and testing the psychometric properties of the engineering focused instrument, the researcher developed the Engineering Global Preparedness

Index, (EGPI), an instrument that is intended to measure the preparedness of engineering students for global workforces. This paper describes the instruments' development and a multi-university research study that utilizes the Index as its primary measure. The study is guided by three important research questions: *What role do experiences and engineering education pedagogical practices play in preparing engineering students for global workforces? Are international students better prepared for global workforces? Do international field and service experiences assist students in preparing for global engineering workforces?*

This paper presents on multi-university, three-year research effort from implementation of the Engineering Global Preparedness Index (EGPI). The EGPI is aligned both to the National Academy of Engineering 2005 publication, *Engineers for 2020* and to the Accreditation Board for Engineering and Technology (ABET) outcomes. Accordingly, the instrument is directly aligned to engineering ”soft skills” that are often difficult to measure via individual course exams and projects. The EGPI is not a student survey of perception of their learning; rather, it is a direct measure of how prepared students are for global workforces in areas of *communication, professional ethical responsibility, understanding of global issues and lifelong learning*. Subscales for the index were developed accordingly, while also aligning with sound theoretical and empirical research on global citizenry[9, 10] and the National Academy's expectations for global preparedness. The following four subscales are utilized as metrics in the engineering global preparedness index (EGPI). These metrics are directly aligned to important "soft skills" needed both by engineers and other professionals who work in global workforces. Additionally, the index is theoretically grounded in global citizenry theory as prescribed by Zeichner[9] and Banks.[10] A description of each EPGI construct or subscale follows in the text below.

Engineering Ethics: Depth of concern for people in all parts of the world; sees moral responsibility to improve conditions and take action in diverse engineering settings.
Engineering Efficacy: Belief that one can make a difference; support for personal involvement in local, national, international engineering issues and activities towards achieving greater good using engneering technologies.
Engineering Global-centrism: Valuing what is good for the global community in engineering related efforts, not just one's own country or group; making judgements based on global needs for engineering and associated technologies, not ethnocentric standards.
Engineering Community Connectedness: Awareness of humanity and appreciation of interrelatedness of all peoples and nations and the role that engineering can play in improving humanity and meeting human needs; global belonging or kinship as member of "human family" within the modern world.

Instrument Design and Testing

There are total of 30 items on the EGPI with 3-6 items per subscale. This item distribution and scale total is supported by item response theory[11] for designing difficult to observe (soft skill) constructs, as is the case of global preparedness. The table (1) below provides sample items for each of the four subscales.

Table 1: Sample Items by Construct

Subcale/Construct	Sample Index Item
Engineering Ethics	Engineers in my country have a moral obligation to share their engineering knowledge with the less fortunate people of the world.
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 Global-centricism	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.

A minimum of two items per subscale in the index are reverse scored items in the index in support of best practices in survey development, and true measurement of student knowledge (rather than student perception) beyond what is self-reported. A four point Likert-type scale was employed for the Engineering Global Preparedness Index (EGPI).

In terms of index design, reliability testing and and validation, an initial set of items were designed and piloted with a group of undergraduate and graduate engineering students in 2007. Once the initial set of items for the EGPI were developed, five engineering Ph.D. students were chosen to engage in a "cognitive interviewing technique" to test the content and construct validity of each index item. Accordingly, the Ph.D. students completed the draft EGPI and then were interviewed to understand the rationale that they followed for making specific response choices. Woolley, Bowen and Bowen[5] describe this cognitive interviewing process as having the individual discuss the message behind his or her responses. In particular, these scholars' measurement research has provided credibility for this instrument design technique as a powerful and viable means of developing content and construct validity of survey-type self-report instruments for measuring beyond perceptual skills. All EGPI items were revised with specificity according to the results of the cognitive interviews described above. Post completion of the cognitive interview process and revision, the EGPI was administered with undergraduate and graduate engineering students in diverse universities (public and private, large and small) across the nation.

Prior to comparing the means by subscales across student groups, the reliability of the subscales was tested using Cronbach's correlational analysis procedures. Table 2 (below) presents the reliability coefficients by subscale for the Index. This information provides inmportant indicators of the reliability of the EPGI. As revealed by Cronbach's work on instrument reliability, any alpha value that computes to ~ .70 or greater is considered moderately to highly reliability in measurement of the knowledge and understanding of what it is intended to measure. Accordingly, the EPGI

Table 2: Reliability Coefficients

Subscale	Cronbach's Alpha Value
Engineering Ethics	.79
Engineering Efficacy	.70
Engineering Global-centricism	.68
Engineering Community Connectedness	.69
Overall Reliability	.77

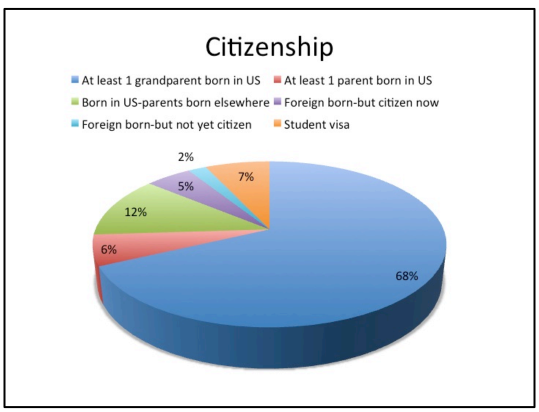
is quite reliable per its alpha coefficients.

Not only were the reliability metrics of the EPGI computed, this research involves a deliberate comparison of the means by subscale of the instrument between particular student experience groups. This comparison is made in an attenpt to determine the role that engineering education programs and in particular international experiences play in preparing engineering students for globally focused workforces. These results and comparisons across groups are interesting and diverse. They vary by EPGI construct (as delineated by each subscale). The results of these analyses provide important information about the "start to finish" preparedness of students for engineering global workforces as recommended by the NAE.[2]

Study Population

The study participants came from a broad array of engineering students in both undergraduate and graduate engineering at six major research universities. A total of 493 students participated in this study. Equal numbers of undergraduate and graduate engineering students were included in the sample with 14% of the students self identifying as international students and a 34-66 percentage split between female and male students, respectively. This popuation diversity was deliberately achieved (in other words, a purposeful sampling of undergraduates and graduates from across universities was completed) with the intention of testing diverse variables associated with global preparedness during the study. Figures 1-4 (below) illustrate the study populations' socio-demographic makeup and international experience set.

Figure 1: Origin of Citizenship



As indicated in Figure 1, approximately 14% of the entire sample size was comprised of international students. It is important to note that the majority of students were born in the United States, with at least one grandparent born in the US (68%) indicating that they were not first generation US students. Figure 2 (below) describes the percentage of the sample that has resided within another country for an extended period of time in their life. This is an important factor to take into account, particularly when considering the impact that international experience could potentially have on overall global preparedness.

Figure 2: Residence in Non-US Country

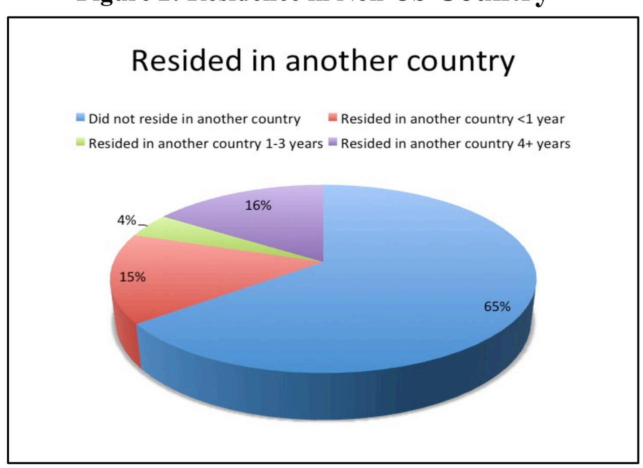


Figure 3 (below) indicates the participants' involvement in international community service efforts. In the study sample, nearly 20% of the participants were involved in some form of international community service associated with university education for an extended period of time. As previously stated, international community focused experience potentially impacts overall global preparedness due to the exposure that individuals encounter when time is spent residing in and participating in efforts within other countries. This is supported by the literature on international education in university settings.

Figure 3: International Community Service

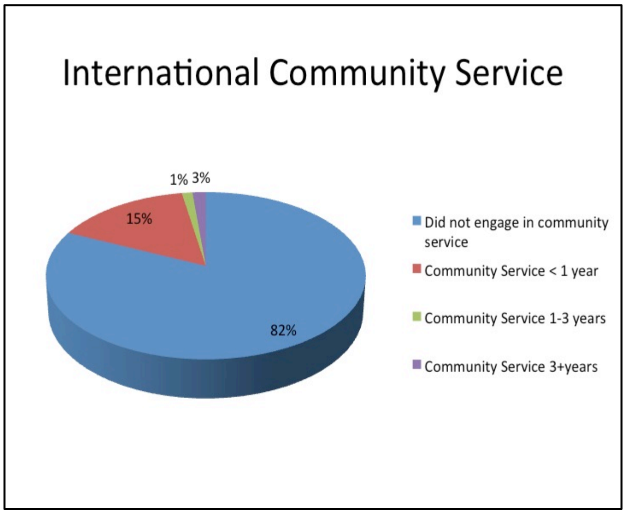
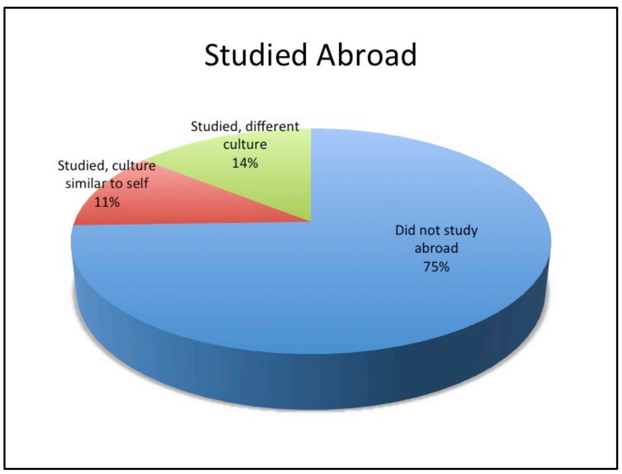


Figure 4 (below) further describes the sample in terms of the percentages of students that have been involved in international studies (study abroad). Approximately 25% of the participants reported studying abroad, further indicating whether or not the culture was similar or different to their culture of origin. Importantly, while the Academy is recommending preparedness for global workforces, the majority (75%) of the students in this study did not have a study abroad experience while in college.

Figure 4: Students With Study Abroad Experiences

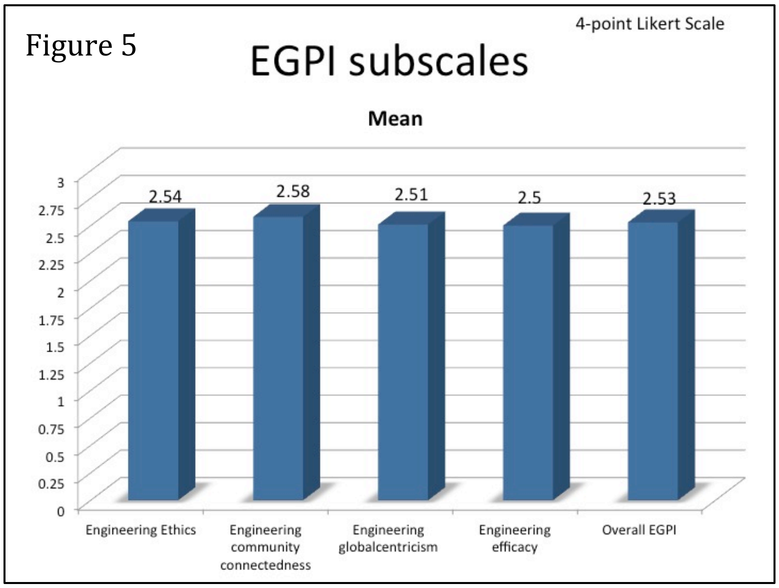


Data Analyses

Several analytical procedures were utlized in this research beyond the descriptive statistics represented in Figures 1-4. Initially, descriptive statistical analyses were performed on all of the EGPI subscale means. Secondarily, in an effort to determine which factors predicted global prepareness, statistical correlational analyses and regression techniques were perfomed. Results are presented below.

Study Results

The results of this study vary greatly by subscale construct. The results provide imortant information that informs the engineering education research community about the importance of training engineers for global workforces and monitoring their progress and experiences as they prepare for engineering field. Figure 5 that follows represents the means for each of the constructs. It offers a comparison by subscale means across student groups. As described, these descriptives are indicative of the preparedness of the diverse engineering student population.



A regression analysis was conducted to identify significant predictors of engineering global preparedness in the study sample. Numerous significant findings were uncovered through these analyses. The comparative analyses were conducted for overall engineering global preparedness as well as individual subscales of the Engineering Global Preparedness Index (EGPI).

Results indicate that both being an international student (participants who reported that they were not yet US citizens) ($\beta=0.194$, $p<0.01$) and present in the United States with a student VISA ($\beta=0.256$, $p<0.01$) was highly predictive of increased engineering ethics. In addition, students that reported living in another country from 1-3 years were also likely to report higher levels of engineering ethics ($\beta=0.131$, $p<0.05$). The results also revealed that being foreign born and not yet a citizen of the United States was a predictor of higher levels of community connectedness ($\beta=0.146$, $p<0.05$). Moreover, results indicated that dominant ethnic group (namely the reported Caucasian ethnic group) held lower levels of global centrism ($\beta=-0.203$, $p=0.06$).

In terms of engineering efficacy, the results indicate a negative/inverse relationship between engineering efficacy and being an international student ($\beta=-0.215$, $p<0.05$). This finding may be attributed to fundamental difference in educational systems, structures and pedagogical practices between students' home country and the United States university systems, which may, in turn, contribute to lower self-efficacy in engineering.

Lastly, the regression analyses revealed that studying abroad in a culture different from students' culture of origin was predictive of high levels of overall global preparedness ($\beta=0.177$, $p<0.05$). This may be explained through exposure to different cultures and experiences and is supported by the literature describing student global citizenry.

In addition to regression analyses, correlational analyses were conducted to examine relationships between study variables with granularity. With regard to engineering ethics and engineering community connectedness, having a student VISA also had a strong positive correlation with both subscales ($r=0.208$, $p<0.01$, $r=0.157$, $p<0.01$, respectively). This may be attributable to global experiences often seen with international students. In addition, growing up in a small town was inversely correlated with both engineering ethics and engineering community connectedness ($r= -0.359$, $p<0.01$, $r= -0.296$, $p<0.01$, respectively). This observed negative relationship may be attributed to the limited experience that the participants may have had with population diversity as a function of growing up in a small town where overall population is sparse. Additional correlational analyses revealed negative relationships between growing up in a rural area and engineering ethics and engineering community connectedness ($r= -0.142$, $p<0.01$, $r= -0.112$, $p<0.05$, respectively). This again may be attributed to potentially limited global experiences in small, rural communities. Contrarily, growing up in a large, urban community was strongly and positively correlated with international community service ($r=0.173$, $p<0.01$).

Discussion and Future Work

This paper presents research on the multi-university results of a newly designed engineering global preparedness index. The research results suggests that programs should develop engineering students capable of performing competently in science and engineering professions and communicate effectively with other professionals in the globalized world through an experience that provides on the job training coupled with extensive cultural preparation (eg. International experiences).[12] The index provides engineering educators with insight as to the "soft skill" areas that must be provided in terms training and education (particularly internationally focused training, for engineering candidates if engineering students are to be fully prepared to work in global societies. The results and comparisons, and predictive factors described above clearly inform engineering education pedagogical practices both inside and beyond classroom walls. An index of global preparedness is an important tool for measuring engineers' preparedness for global workforces.

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