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Preparing Engineers for Global Workforce: A Research University's Response

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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, 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 National Academy of Engineering charges universities and colleges to prepare engineers that are leaders in engineering fields with strong communication, leadership and interdisciplinary research, and professional skills in diverse in engineering environments.

This paper describes the University of Southern California, Viterbi School of Engineering's response to this important National Academy of Engineering challenge. This paper will describe both curricular research and metrics associated with global preparedness for working in diverse engineering contexts. In this study, engineering students received interdisciplinary globally focused training via their coursework and laboratory experiences and were assessed as to their preparedness to work in global workforces and research environments. A global preparedness index was developed and administered to assess the impact of these educational and research experience with a summative focus. Results of this important metric were compared to students' course grades, engineering efficacy and outcomes-based academic program success. Results of this research indicate that engineering students who were most globally prepared were also most efficacious and received higher grades in courses. Additionally, diversity in preparedness among the subscales of the index was noted, suggesting that students with diverse demographic profiles have diverse preparedness indices.

Keywords: Global, global preparedness, engineering education, preparation for global workforces

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 related to science, technology, engineering and mathematics (STEM) education, and 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 high-level skills including innovation, a problem solving approach, and leadership to their workplace. Accordingly, there are recent reforms in engineering education implemented as efforts to meet the changing needs of engineers nationally and globally, however sparse research exists that comprehensively assesses and evaluates the outcomes associated with such engineering education reform efforts, and in particular the impact of academic preparation on engineering students' preparedness for global engineering workforces.

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 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, per the NAE, measure preparedness for global impact.

Global Preparedness

While STEM graduate programs in the U.S. are dominated by international students (foreign students made up 47% of all graduate enrolments in engineering in the U.S.), other countries are outpacing the U.S. in producing scientists and engineers: of all undergraduate degrees awarded worldwide in science and engineering, 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 this effort. Global preparedness cannot be measured with a traditional examination as this metric 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 international readiness for employment. Unfortunately, none of these metrics exactly aligned to engineering career preparedness in the way that this paper intends to describe.

Research Design and Metric Development

After exploring researched metrics in engineering education that measure students' preparedness for global workforces and discovering that there are no specific metrics with quantitative foci, I set out to create and test a survey instrument (index) that could measure this important preparatory construct. I have been involved with an international research group that was attempting to measure teachers' global citizenry at preservice levels. This group had recently developed an instrument to test the constructs associated with global citizenry for teachers. Accordingly, I set out to investigate the constructs associated with the teacher instrument and to adapt the teacher instrument to design an engineering focused measurement of global

preparedness. As such, the primary research question guiding this paper is: *How can we measure the global preparedness of graduate and undergraduate engineering students?*

In designing my instrument I used the same subscales of the teacher instrument and altered individual survey items within the subscales to reflect specific engineering foci as recommended by the National Academy of Engineering. This paper presents the pilot research results from implementation of the global preparedness index that I designed for engineering students. The following seven subscales were utilized in creation of this global preparedness index.

Ethic of Responsibility: Deep personal and care concern for people in all parts of the world; sees moral responsibility to improve conditions and take action in engineering settings.

Cultural Pluralism: Appreciation of diversity of cultures and dispositions in STEMs fields: belief that all have something of worth to offer to theses workforces; enjoyment of exploration and trying to understand other cultures in the contexts of STEMs fields.

Personal Efficacy: Belief that one can make a difference; support for personal involvement in local, national, international engineering issues and activities towards achieving greater good.

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 in engineering and associated technologies, not ethnocentric standards.

Interconnectedness and Global Kinship: 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

Skilled Disposition and Open-Mindedness: Valuing of alternative perspectives and points of view; ability to suspend judgement and change one's views; collaborates and interacts with others as part of the process of forming one's position on issues.

Peaceful Resolution: Commitment to and belief in peaceful resolution of conflict and the role that engineering can play in these resolutions; belief that even competitive activities should adhere to principles of non-violence and global safety.

There are total of 60 items on the Index with 6-8 items per subscale. This item distribution and scale number is supported by item response theory for designing difficult to measure constructs.[8] Table 1 provides sample items for each of the seven subscales.

Table 1: Sample Items by Construct

Subcale	Sample Item
Ethics of Responsibility	Engineers in my country have a moral obligation to share their engineering knowledge with the less fortunate people of the world.
Cultural Pluralism	Enhancing a person's ability to be part of a multicultural society and global engineering economy should be part of higher education in today's universities.
Personal 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.
Global-centricism	I think my country needs to do more to promote the welfare of different racial and ethnic groups in engineering industries.

Interconnectedness and Global Kinship	To treat everyone fairly, we need to ignore the color of people's skin.
Skilled Disposition and Open-mindedness	I try to consider different points of view on an issue in my engineering work before making up my own mind, even when I have a strong first impression.
Peaceful Resolution	If people in engineering industries were treated more fairly, there would be fewer problems and less conflict and disagreement in this country.

A minimum of two items per subscale is a reverse scored item in the index in suport of best practice in survey development. A five point Likert type scale was employed for the Engineering Global Preparedness Index (EGPI).

Once I designed my initial set of items for the EGPI, I engaged in a "cognitive interviewing technique" to test the content validitity of each index item. I had 4 Ph.D. students complete the draft Index and then I interviewed them to understand the rationale that they followed for making specific response choices. Woolley, Bowen and Bowen describe cognitive interviewing as having the individual discuss the message behind his or her responses.[8] These scholars' measurement research has lent credibility for this technique as a powerful and viable means of developing content and construct validity of survey -type instruments. I adjusted all items according to the results of the set of three cognitive interviews. Once I was satisfied with the remaining index items, I piloted the index with undergraduate and graduate engineering students. Results of the pilot are presented in this paper.

Study Population

As previously described, the study participants came from a broad array of engineering students in both undergraduate and graduate engineering at a major research university. A total of 147 students participated in the pilot. Equal numbers of engineering students at undergraduate and graduate levels were included in the sample with 32% of the students indicating that the were international students and a 32-68 percentage split between female and male students respectively. This popuation diversity was deliberately achieved in hopes of testing diverse variables associated with global preparedness during the pilot.

Study Results

The results of this pilot study are intersting and diverse. They vary greatly by degree objective and subscale construct. While this is a pilot study, the results provide important information that infrms me and others about the importance of training engineers for global workforces and monitoring their progress as they prepare for engineering field. As an initial step in this research I computed edescripvestatistics on the index subscales. Results are presented below as figure 1. Additionally, and prior to comparing the means by subscales across groups, I tested the the reliability of the subscales. Table 1 represents the reliability coefficients by subscale.

Table 2: Reliability Coefficients

Subscale	Cronbach's Alpha Value
Ethics of Responsibility	.72
Cultural Pluralism	.76
Personal Efficacy	.79
Global-centricism	.84
Interconnectedness and Global Kinship	.71
Skilled Disposition and Open-mindedness	.78
Peaceful Resolution	.81
Overall Reliability	.81

Figure 1 that follows describes the means for each of the subscale constructs. It offers a comparison by subscale means across student

groups, divided by the students' career objective.

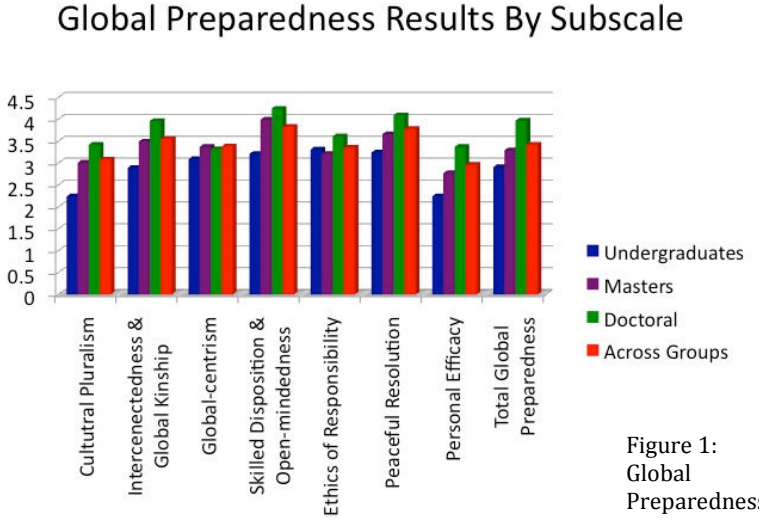

Figure 1: Global Preparedness by subscale and group

It is intersting to note that the means of the various subscales vary greatly. The doctoral students in the study sample had the strongest global preparedness overall (m=3.97). Additionally, this sub group of students had higher subscale means in all areas. This could be explained by the advanced age and experiences inside and outside of the university of the doctoral students. The master's students in general had higher mean global preparedness across scales when compared to the undergraduate students, however in the area of ethics of responsibility, the undergraduates (m= 3.31) had higher mean scores than masters students (m= 3.21). Perhaps this particular subscale indicates the undergradates' propensity for altruism. This altruism often decreases as adults' experiences increase as sinicism often sets in as a result of experiencing diverse and negative experiences in life. Overall, the highest area of global preparedness was in the area peaceful resolution (m= 3.78) and the lowest area of preparedness was in cultural pluralism (m= 3.01). Peaceful resolution is an important skill and one that may be closely aligned to the political ideology ogf many young students today (particularly during war time as students are presently experiencing). Cultural pluralism or the appreiciation of culturals and dispositions may be more difficult for students to understand. It also may be more difficult to accurately measure this particular construct. Accordingly, these two reasons provide rationale for each of the respective results.

Discussion and Future Work

This paper presents research on the pilot results of the newly designed global preparedness index. Results of this pilot are preliminary as the population sample size is rather small (N=147). The index provides us with insight as to the "soft skill" areas that me must provide training and education for engineering candidates if we want our engineering students to be fully prepared to work in global societies. Post pilot, a full, large-scale study should be conducted with the unit with sample sizes exceeding 500 per sub-group. An index of global preparedness is an important tool for measuring engineers' readiness for global workforces. This index can be used with diverse engineering students in their diverse fields.

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