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Exploring Engineering Education in Broader Context: A Framework of Engineering Global Preparedness

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Abstract

Both the National Academy of Engineering and engineering education researchers underscore a necessity that U.S. engineering graduates be capable of collaborating across national boundaries to successfully "encounter worlds of professional practice that are increasingly global in nature." As a result, this emphasis requires engineering educators and professionals to better understand what constitutes a globally prepared engineer and the types of learning experiences foster preparation of such an engineer.

This paper offers an overview of a NSF funded multi-university research program that investigates how globally focused learning experiences within engineering (both co- and extra-curricular) impact students' global preparedness. The research protocol involves three studies and dissemination platform, each of which is in different levels of completion.

Results from this study offer the engineering education community a set of impactful and flexible research-based globally focused engineering education pedagogical practices that correlate to learning, diverse student populations, and program types.

Introduction

This multi-university research initiative examines how various international education opportunities contribute to the global preparedness of engineering graduates. This initiative is funded by the National Science Foundation, which has concluded, "The frontier challenges of science and engineering are increasingly global. [Therefore] Future generations of the U.S. science and engineering workforce must collaborate across national boundaries and cultural backgrounds, as well as across disciplines to successfully apply the results of basic research to long-standing global challenges such as epidemics, natural disasters and the search for alternative energy sources."[1] Clearly, the global preparedness of engineering students is becoming an important educational outcome and is a natural extension to recent concerns by a number of national commissions as well as scholars, who have also noted the impact of globalization and the implication for continued U.S. economic leadership.[2,3,4]

Given this concern, engineering educators have been rethinking the skills and tools that their graduates will need to function effectively with their international counterparts. To our research team, this implies the Accreditation Board for Engineering and Technology's (ABET) minimal set of eleven accreditation outcomes should also include the ability to work cross-culturally, especially on the international playing field.[5,6] Hence, the purpose of our research collaboration is to explore and identify the various ways that this can be accomplished in an already crowded curriculum.

Specifically, we aim to better understand how international experiences both in and out of formal curricula impact students' global preparedness. This research is timely as 21st century engineers are being called upon to solve complex problems in collaborative, interdisciplinary, and cross-cultural contexts. This requires ". . . a new type of engineer, an entrepreneurial engineer, who needs a broad range of skills and knowledge, above and beyond a strong science and engineering background . . ."[7] Yet, most evidence about how international experiences and education impact engineering students lacks empirical research to guide educational practices.

Engineering faculty have anecdotally recognized that students who participated in study abroad programs develop skills in problem solving, in cross-cultural communication, and in working effectively with diverse teams. Living internationally prepares graduates to better adapt to new environments, to develop a greater understanding of contemporary issues, and to put engineering solutions in a global and social context.[8] However, further research is required to fully support, quantify, and generalize these findings.

This research addresses two gaps in engineering education: 1) the need for a systematic study of curricular and extracurricular offerings in international engineering education, and the extent to which these different international academic and non-academic experiences improve the global preparedness of engineering students; 2) the identification of the key constructs that characterize a globally prepared engineering graduate. By doing this, we will contribute to the understanding of how engineering students become globally prepared, while providing educators with important, actionable items about curricular and extracurricular practices that can enhance engineering global preparedness. This paper provides an overview of the research endeavor that addresses these two literature gaps.

Study Objectives and Hypotheses

This project is currently being conducted by a multidisciplinary team from four universities and has four objectives:

1. Develop with experts an operational model of international experiences specific to engineering education; establish constructs of international education and learning outcomes, develop a framework, and match these constructs with appropriate assessment instruments.

2. Conduct a mixed-methods experiment among the four collaborating schools using a triangulation study employing two established assessment instruments – the GPI, and EGPI – that each captures different constructs. Using statistical methodologies, map outcomes to educational practices, institutional characteristics, and student backgrounds. Using results from the indices, conduct a series of interviews to tease out the underlying experiences that contribute to achieving global preparedness.

3. Conduct a larger cross-institutional quantitative study of 12 to 15 different types of engineering schools to analyze the impact of various international experiences, both

within and outside the curriculum. Included will be such experiences as military service, living internationally prior to college, or participating in an extended service project.

4. Disseminate results to the larger engineering education community using an innovative, online approach that both queries the larger population of engineering programs, and updates in real (or near real) time aggregate results as to the extent the various models for developing global preparedness are being employed, as well as an assessment of their effectiveness.

In carrying out this research, the study tests three hypotheses:

First, that the *types of international experiences are correlated with student learning outcomes*. That is, the variety of activities and degree of international exposure that engineering students have is positively correlated with global preparedness. Second, *specific approaches and/or experiences along with content delivery are correlated with student learning outcomes*. Specifically, instructional approaches, extracurricular experiences, and student background factors impact the degree to which student learning outcomes are achieved. Third, *different international activities positively affect the attitudes and preparedness of different engineering student groups (e.g., minorities, women, foreign nationals, veterans)*. Through modeling efforts the team will connect student learning outcomes directly to educational practices, institutional characteristics, and student factors. When completed, this study will *provide the engineering community with a set of practices correlated with international learning, various student populations, and types of programs.*

Definitions

The following definitions are central to this project and are used throughout this paper.

- <u>International education</u>: "Learning opportunities designed to help individuals understand other cultures and nations; communicate across borders; and acquire an understanding of the cultural, social, and political systems of other nations . . . a course, program, or activity would be considered international if it includes perspectives, issues, or events, from specific countries or areas outside the United States.*"*[9]
- <u>Global competency</u>: Parkinson has suggested the attributes of a globally competent engineer,[10] while Deardorff has identified 22 agreed upon components of intercultural competence. To Deardorff, intercultural competence is the development of one's skills and attitudes in successfully interacting with persons of diverse backgrounds.[11] For purposes of this paper, global competency and intercultural competency will be used interchangeably.

- <u>Global preparedness</u>: Though Parkinson and Deardorff identify the necessary knowledge, skills and attitudes, in our research we take these critical aspects further to define global preparedness – the readiness to engage and effectively operate under uncertainty in different cultural contexts to address engineering problems. Global preparedness brings together the set of congruent behaviors, attitudes, and policies in a system, agency, or among professionals, enabling that system, agency, or those professionals to work effectively in cross-cultural situations.[12]

The State of International Experiences in Engineering Education

While the engineering student participation rate in international education programs is gradually increasing, still only about 11,000 U.S. engineering students participated in study abroad in 2011-12 compared to 141,000 international students who studied engineering in the U.S. during the same academic period. Stated another way - 3.9% of those studying abroad in 2011-12 were engineering students, compared to 18.8% of the international students studying in the U.S. Given that only 5% of U.S. students are studying engineering, the concern is evident[13].

While there is a growing consensus that globalization requires U.S. engineering students to acquire new skills, there is little agreement as to what those skills are. ABET accreditation criteria simply calls for engineering programs to demonstrate that graduates have "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context"[14]. The Association of Public and Land Grant Universities (then NASULGC) proposed learning outcomes for globally competent graduates: a diverse and knowledgeable worldview; comprehension of the international dimensions of the major field of study; ability to communicate in another language; ability to understand the importance of and exhibit sensitivity and adaptability in cross-cultural communications and group experiences; experiences outside the U.S.; and a readiness to continue to develop global competence throughout their adult life.[15] Other experts have concluded that engineering and science students must possess domain knowledge (expertise in a specific field) and professional competence (practical ingenuity, creativity; cognitive skills; communication and social skills; and an ability to work in teams or unite individuals possessing diverse skills to a common purpose).[16] What is strikingly absent in this literature regarding global preparedness is a direct connection to how it should be assessed, especially for STEM students. This research is significant because it will identify the outcomes from international engineering education and specifically correlate their measurement with appropriate assessment instruments.

Assessment Instrument Overview

Although several potential instruments exist (e.g., BEVI, IDI, MGUDS)[17,18,19] this study uses two established inventories for assessing outcomes related to global learning, the Global Perspective Inventory (GPI) and the Engineering Global Preparedness Index (EGPI). The GPI has been administered by 150+ institutions and over 100,000 students, staff, and faculty have completed the GPI since its development in 2008[20]. The EGPI was designed to address the metric of global preparedness that most existing instruments cannot. The EGPI focuses on programmatic elements of engineering education that may assist in global preparedness. Our research team chose these two instruments because of their theoretical alignments with the research objectives, and their extensive application in diverse student populations across the nation. A more thorough description of both instruments is provided below.

The Global Perspective Inventory (GPI). The GPI, developed by Braskamp, Braskamp, and Merril, is anchored by two theoretical perspectives grounded in holistic human development: *intercultural maturity (e.g. trying to make sense of their journey through life)* and *intercultural communication (e.g. the thinking, feeling, and relating domains)*[20]. The instrument draws on the work of Kegan, who argued that as people grow, they are engaged in meaning making[21]. It identifies three major domains of human development and associated questions:

1. Cognitive: This domain considers the question, "How do I know?" It is centered on one's knowledge and understanding of what is true, what is important to know, and how one determines each of these things. This domain includes the subscales of *Knowing and Knowledge.* Knowing is the degree of complexity of one's view of the importance of cultural context in judging what to know and value. Knowledge is the degree of understanding and awareness of various cultures and their impact on our global society; it is also the level of proficiency in more than one language.
2. Intrapersonal: This asks "Who am I?" and seeks to understand how one integrates one's personal values and self-identity into one's personhood and how one becomes more aware of this process. The Intrapersonal domain consists of the *Identity* and *Affect* subscales. Identity is a combination of the level of awareness of one's unique identity and degree of acceptance of one's ethnic, racial, and gender dimensions of that identity. Affect is the level of respect for and acceptance of cultural perspectives different from one's own and degree of emotional confidence when living in complex situations.
3. Interpersonal: This asks "How do I relate to others?" This domain considers one's willingness to interact with persons with different social norms and cultural backgrounds, acceptance of others, and comfort with relating to others. The Interpersonal domain consists of *Social Responsibility* and *Social Interactions* subscales. Social Responsibility measures the level of interdependence and social concern for others. Social Interactions measures the degree of engagement with others who are different from oneself and degree of cultural sensitivity when living in pluralistic settings

The Engineering Global Preparedness Index (EGPI). The EGPI is aligned to both ABET's more difficult to measure professional skills and the NAE's, *Engineer of 2020*. The EGPI is not a survey of perception of learning; rather, it directly measures how prepared students are for the global workforce. The index is grounded in global citizenry theory.[22,23] It utilizes four subscales each of which have been validated using item response theory[24] and extensively tested for reliability:

Global Engineering Ethics and Humanitarian Values: This construct refers to the depth of concern for people in all parts of the world, with a view of moral responsibility to improve life conditions through engineering problem solving and to take such actions in diverse engineering settings ($\alpha = .90$).

Global Engineering Efficacy: This refers to the belief that one can make a difference through engineering problem solving and is in support of one's perceived ability to engage in personal involvement in local, national, international engineering issues and activities towards achieving greater global good using engineering problem solving and technologies (α = .85).

Engineering Global-centrism: This refers to a person's value of what is good for the global community in engineering related efforts, and not just one's own country or group. It refers to ones ability to make sound judgements based on global needs in which engineering and associated technologies can have impact on global improvement (α = .79).

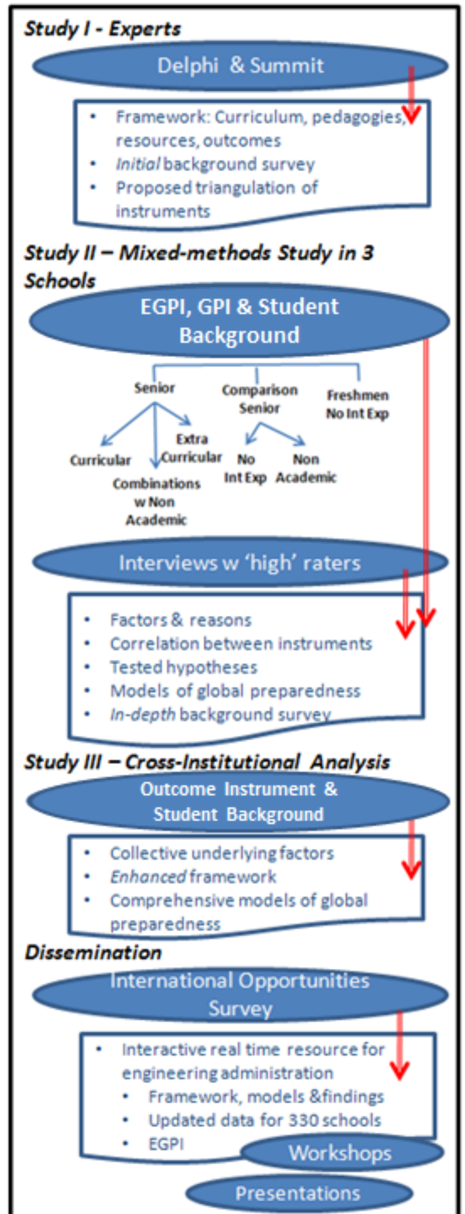

Figure 1. Research Roadmap

Global Engineering Community Connectedness: This refers to one's awareness of humanity and appreciation of interrelatedness of all people and nations and the role that engineering can play in improving humanity, solving human problems via engineering technologies, and meeting human needs across national boundaries (α = .72).

Research Design

Our research involves three separate but integrated studies with a dissemination platform that Figure 1 depicts. Each study is described below.

Study 1- Expert Developed Model

The purpose of Study 1 has been to establish a baseline model of the global engineer's professional attributes, to expand these attributes to constructs and learning outcomes, and to ultimately develop complementary instruments focused on measuring the outcomes. To do this, the team has conducted a comprehensive Delphi study, identifying and then obtaining opinions from experts on: the constructs and the learning outcomes of these constructs based on the initial set of attributes. The outcomes from this study are being used to produce a model of global engineering preparedness, which is providing the basis for a student background instrument that will be employed in Study 2.

The Delphi study consisted of three rounds that culminated with a face-to-face meeting followed by a fourth and final analytical and mapping synthesis. The sample included 18 Subject Matter Experts (SMEs) included engineering faculty with experience in international education, international education practitioners, industry representatives familiar with international engineering assignments, and project officers from agencies that sponsored international engineering opportunities. In Round 1 participants addressed two open-ended questions: First, what characterizes a globally prepared engineer and, second, what are the learning experiences necessary to produce such an engineer. These responses were used to construct a questionnaire that participants completed in the second round. From the participants' responses areas of consensus and divergence were found. In the third round, SMEs revised their judgments and provided their rationale. These were then discussed at a face-to-face "summit," at which participants came to consensus about the learning outcomes and programmatic elements that influenced the quality of global experiences, and addressed the connections to global preparedness. As part of the summit, the SMEs created semantic maps of global engineering preparedness outcomes. Following the summit, these were then synthesized into a single map that was vetted by the SMEs during the fourth and final round. The resulting map provides an organizing framework for international engineering education and provides the interrelationships among engineering global preparedness and three other broad categories: intercultural contextual knowledge, personal and professional qualities, and cross-cultural communication skills and strategies.

Study 2 Mixed Methods Experiment

The second study (currently in progress) uses a mixed-methods quasi-experimental design to measure learning outcomes identified in Study 1, which are mapped by the two aforementioned outcome instruments, EGPI and GPI. A background survey was also developed to assess which underlying characteristics of students and their respective international/intercultural experiences contribute most to the global preparedness outcomes identified in Study 1. Samples of senior engineering students from four institutions, who have engaged in an international experience, are being invited to complete the set of instruments (EGPI, GPI, and background survey). The background survey instrument consists of four components: profile characteristics (e.g. gender, age, class standing,), educational background (e.g. university, major, QPA), travel abroad/ international experiences (e.g. level of interest in international issues, foreign language proficiency), and characteristics of the international experiences (e.g. programmatic elements of experiences such as duration, amount of reflection, and comfort zone). The background survey will be used as independent predictor variables to help explain the results of the outcome instruments (EGPI and GPI). In addition, each site has recruited a comparison set of senior engineering students who have not had an academic-based experience and a third sample of incoming freshmen without international experience to provide a baseline. After analyzing the data, a smaller subset of these students will be invited to participate in follow-up interviews. Specifically, we will interview approximately 20 students at each institution who "scored" high on the outcome instruments (EGPI and GPI). The primary purpose of these follow-up interviews is to further tease out the underlying reasons for how these students' achieved relatively high levels of global preparedness. A set of probes based on the constructs of the two instruments and background survey are being developed to guide our questioning. We are interested in determining for specific outcomes the extent that it is the result of personal factors, prior experience, curriculum models, pedagogy, or institutional resources that were identified in Study 1. We will use grounded theory [25] to enhance these initial categories and their dimensions; and to identify relationships between these categories and student performance on the two instruments. This will result in a more rigorous student background survey, more robust models for how global preparedness is achieved, empirical correlations between the instruments, and tested hypotheses.

Study 3 Cross Institutional Study

As mentioned, Parkinson identified 24 exemplar engineering schools that promote international education. In Study 3 (planned for the near future), the researchers will further test the hypotheses by inviting 12 to 15 engineering schools to participate in an in-depth study to analyze engineering students' global preparedness as the result of their academic and non-academic international experiences. From Study 2, the team will have an improved and finalized student background instrument with definitive factors that are linked to global preparedness; and the researchers will use this instrument in conjunction with most likely either the EGPI or GPI. The purpose of the third study is to further test and explore further the hypotheses and findings from the second study.

Dissemination Platform

Both traditional and innovative means for dissemination will be used. We will leverage the extensive networks that we have developed to cultivate an influential group of users for distributing the research results, engaging them in both development and dissemination activities. In particular, we propose a creative way to both disseminate our results to a wide spectrum of engineering programs, while at the same time asking them to assist us in further extending our data base and findings; so that in the end, we will have obtained an accurate picture of the various international educational experiences provided in U.S. engineering schools. At the completion of Study 3 we will have a well-defined framework. Using this data, we will have constructed models, validated through interviews, that will better enable us to not only identify factors, including various pedagogical approaches, and formal and informal educational models that lead to global preparedness. This will be organized in a manner that will allow translation into practice for engineering administrators and faculty as they consider how best to prepare their students for the global economy. Concomitantly, we will systematically utilize available resources including the web to determine the global opportunities that each U.S. engineering school offers its undergraduates, including study abroad experiences, and active chapters of Engineers without Borders and Engineers for a Sustainable World.

Conclusion

More than 430,000 students are enrolled in U.S. engineering programs, producing close to 70,000 B.S. engineering graduates annually. An increasing percentage of graduates are employed in international environments. Further, the demand for globally prepared engineers will continue to increase; faculty and administrators will need to offer opportunities to acquire such skills, knowledge, and mindset. This study will provide key data and tools to facilitate the development and improvement of educational opportunities to stimulate international education among undergraduate engineers. Faculty will have access to information on what is typically taught and how institutional and course factors can impact positive student learning outcomes. Although this study focuses more specifically on engineering, the results will be generalizable to other STEM disciplines attempting to improve the global competencies of their students.

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