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Assessing the Spectrum of International Undergraduate Engineering Educational Experiences

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1.0 Introduction

The NSF has concluded that "the frontier challenges of science and engineering are increasingly global. 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]. Hence, it is critical to investigate the various ways that engineering students can obtain these important engineering outcomes. Scholars and national commissions have also noted the impact of globalization and the need for continued U.S. economic leadership [2-4]. One result, engineering educators are rethinking the skills that graduates will need to function effectively with their international counterparts. To engineering educators this implies ABET's set of eleven accreditation outcomes should also include the ability to work cross-culturally, especially on the international playing field [5, 6].

While the engineering student participation rate in international education programs is gradually increasing, still only 9,590 U.S. engineering students participated in study abroad in 2010-2011 compared to 141,285 international students who studied engineering in the U.S. during the same academic period. Stated another way, 3.5% of U.S. students studying abroad in 2010 – 2011 were engineers, compared to 18.5% of the international students studying in the U.S. More concerning, the 3.5% of U.S. engineering students studying abroad in 2010 – 2011 represent a 9.1% decrease from the prior year compared to a 4.2% increase in the number of international students studying engineering in the U.S. from 2009 – 2010 to 2010-2011. Given that only 5% of U.S. students are studying engineering, the concern is evident [7].

Engineering programs have recognized that they must produce globally competent graduates who, by working cross culturally, and beyond national boundaries can effectively identify opportunities, understand market forces, and successfully commercialize new technologies. This call has come from professional organizations including the National Academy of Engineering (NAE) and its widely quoted *The Engineer of 2020*, the American Society of Engineering Education and the American Society for Mechanical Engineers [8, 9]. As a result, a small, but growing number of engineering programs now imbed international experiences in their curricula.

There is a second concern: Can these graduates become world citizens? Engineers must understand that in a global context, their solutions - consumer products, system designs, or infrastructure improvements - may have unintended consequences including resource exhaustion and environmental damage that transcend international boundaries. According to philosopher and engineering educator Hans Lugenbiehl, "in the past, engineers have considered a relatively narrow set of consequences from their actions, generally being limited to the safety dimension of their designs. As technical experts on whom society relies, however, engineers are in perhaps the best position to also consider the wider and more long-term ramifications of their engineering decisions." To Lugenbiehl, "engineers can be ethically required to take into account the particular local contexts for which their designs are intended, the effects of the rapid spread of their designs throughout the world, and the effects of their work on the variety of human values as they exist in varying forms in different societies." [10]

<u>1.1 Overarching Research Objectives</u>**:** If we are to enhance engineering students' global preparedness, then we must first better *identify the various ways that global competency can be attained both in and out of formal curricula*, and second *how each approach enhances students' global awareness and preparedness*. Our research objectives are the following.

(1) With experts, we are developing an operational model of international experiences specific to engineering education. We will establish constructs of international education and learning outcomes, and match these to appropriate assessment instruments.

(2) We are conducting a mixed-methods experiment among four collaborating schools. This is being done via a triangulation study using three established assessment instruments that capture different constructs derived from the first objective. Using statistical modeling efforts, we will map outcomes to educational practices, institutional characteristics, and student backgrounds. From the results, we will conduct a series of interviews to tease out underlying experiences that contribute to global competencies.

(3) Finally, we will conduct a larger quantitative study of 15 engineering schools to analyze the impact of various international experiences on engineering students' global competence.

<u>1.2 Focus of Paper:</u> We address here the first objective. Specifically, we are conducting a Delphi study to systematic study curricular and extracurricular offerings in international engineering education. Further, through this Delphi study we identify key constructs that contribute to preparing the 21st century's engineering workforce. When complete, the resulting model will provide taxonomy and an organizing framework for international engineering education. This particular paper reports the nature of the Delphi study, the experts involved in developing the framework, and the initial findings from the first round of three rounds.

2.0 Literature Review

Most contemporary research on how international experiences and education impact engineering students is anecdotal; there is only emergent empirical research to guide educational practices [11]. The factors cited for why engineering students' international experiences include limited specifically designed engineering programs with foci on global competence, and the risk of delaying graduation when international experiences are included as a degree requirement. Yet there are notable exceptions. Parkinson provides an overview of 24 exemplary programs, noting that a few have ambitious goals to increase their number of graduates with an international experience. These include Georgia Tech with a goal of half its student body having an international experience, Purdue with a goal of 20%, and Virginia Tech with a goal of 15% all by the end of 2011 [12]. At the University of Pittsburgh and the University of Southern California 37% [13] and 28.2% [14] of recent engineering graduates respectively had an international experience. Many of these programs are quite innovative. In the past seven years the Institute for International Education has bestowed its prestigious Andrew Heiskell Award for Innovation in Study Abroad on engineering programs. In 2013, the NanoJapan program was also profiled in a National Academy of Engineering report as a model global program for "Infusing Real World Experiences into Engineering Education". As NAE president Dr. Charles A. Vest stated "The basic idea is to create an engineer who has deep, strong, up-to-date technical education and the experiences that wrap around that to enable him or her to work in industry, to work across geographical boundaries, to work with people from totally different professional fields." [15]

Engineering faculty have anecdotally recognized that students who participated in study abroad programs are better problem solvers, have stronger cross-cultural communication skills, work more effectively in groups of diverse populations, and appreciate different perspectives. Living internationally prepares graduates to better adapt to new environments, develop a greater understanding of contemporary issues, and put engineering solutions in a global and social context [16]. However, additional research is required to fully support these findings.

2.1 Approaches to International Education: Universities are using a variety of programmatic and pedagogical approaches to incorporate international education into the engineering curriculum [17]. Common models include: 1) traditional semester or summer study abroad in which students complete courses that count towards their major and general electives [18-20]; 2) short-term, credit-bearing programs lasting less than a month that address a specialized topic related to engineering in a global context [21-24]; 3) comprehensive degree programs in which students are required to obtain proficiency in a second language, complete culture courses, and study or work abroad in addition to their regular engineering courses [25-27]; 4) specialized engineering courses that consider engineering problem solving in a global context but may not require students to travel [28]; 5) international research, internships and co-op experiences [29]; 6) international service learning opportunities including Engineers without Borders and Engineers for a Sustainable World [30]; and 7) graduate research programs, typically funded by external agencies for the promotion of international science collaborations [31]. In addition, there are a variety of experiences that an individual might bring to the college setting (i.e., living in another country prior to college, being a foreign national or permanent resident, being a first generation U.S. citizen, or stationed militarily in another country).

2.2 Learning Outcomes: 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" [32]. We propose that at least three other professional skills are implied – multidisciplinary teamwork, communication, and knowledge of contemporary issues. 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 [33]. Other experts have concluded that engineering and science students must first possess domain knowledge 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) [34]. What is strikingly absent in the literature regarding outcomes for STEM education abroad is a direct connection to how it should be assessed.

3.0 Methodology

To create a baseline model and taxonomy of the global engineer's professional attributes [35]; we expand desired attributes to learning outcomes, outcomes to experiences, and ultimately complementary instruments that focus on measuring the outcomes. To actuate this methodology, we first employed a Delphi method [36] obtaining opinions from experts in the field on: 1) the learning outcomes and 2) the various opportunities and learning experiences engineering students can engage in to develop their global proficiency.

3.1 Overview of the Delphi Method: The Delphi process provides an interactive communication structure between researchers and subject matter experts (SMEs) to develop themes, needs, and directions about a topic. Participants remain anonymous, and responses are reported in aggregate, allowing for a free exchange of ideas among the group. Participants know other SMEs exist, but do not know their names or affiliations. Our Delphi study consists of three iterative rounds, of approximately 30 minutes each. The first round begins with two open-ended questions (described below). These questions serve as the foundation for obtaining specific information from the SMEs. From this information, a structured questionnaire is created. This questionnaire is used for the second round of the Delphi (currently in progress). For round two, SMEs review the summarized categorization of round one data to establish initial priorities for global competence. In addition, we plan to establish areas of agreement and disagreement among SMEs. For the third round of the Delphi, each SME will receive a third questionnaire that includes the items and summarized ratings. SMEs will be asked to review the Delphi one and two results and provide further explanations of the information and judgments given the relative importance of the items. For all rounds, responses are collected via Qualtrics survey software.

3.2 Selection of Subject Matter Experts: The research team created a list of potential subject matter experts (SMEs). We sought a wide range of expertise from the following areas: (1) engineering education, (2) assessment and evaluation, (3) international programming for engineers, (4) high-level industry representatives with knowledge of engineering curriculum who can speak to the competencies engineering students need to be successful in a globalized world, (5) representatives from professional and accreditation-based engineering organizations who can speak to the competencies, and (6) government and non-governmental organization representatives who can provide insights on the impact of international experiences.

An initial list of 87 engineering educators, practitioners, international education society representatives, government representatives, industry representatives, and evaluation experts was developed. Engineering education constituted a large sub-grouping; and hence, they were sorted into primary and secondary potential participants. A goal was to have equal representation across the different arenas. Email invitations were sent to 64 potential participants between mid-September and early October 2012. The email contained information about the purpose of the research, an overview of the Delphi process, as well as information about an optional in-person summit to discuss the study findings and how they will be used in the larger NSF research study. Because the Delphi process maintains that SMEs remain anonymous, those participants who wished to remain anonymous were allowed to opt out of the summit. Twenty individuals accepted the invitation to participate in the study. One person subsequently declined participation; and one individual did not complete the first round of the Delphi study. Seventeen of the 18 SMEs indicated that they spent, on average, 52% of their work related time on *international* training, education or workforce development (stdev = 35.8%, min = 6%, max = 100%). Table 1 provides an overview of the participants in the first round of the Delphi.

Table 1. Distribution of Subject Matter Experts

Field Representation	***Participating SMEs***
Engineering Education	6
Industry Representatives	6
Practitioners	4
Assessment/Evaluation	2
International Education Societies	2

<u>3.3 Round 1 Questions:</u> In October 2012 the SMEs were provided with a link to a Qualtrics questionnaire that consisted of two open-ended essay-based questions. ***Question one*** asked: "What are the specific knowledge, skills, awareness or values that you think characterize a globally prepared engineer?" ***Question two*** asked: "What are the most effective types of learning experiences in producing (graduating) a globally prepared engineer?"

The SMEs were also asked to provide background information regarding their current and past positions, the duration of time spent in their particular positions, as well as their current title and responsibilities. For their current position, we asked the SMEs to provide the percentage of time spent on responsibilities associated with international training, education or workforce development, as well as engineering education or engineering workforce development.

<u>3.4 Approach to Round 1 Analysis:</u> Data for Round 1 was coded and thematically categorized using a constant, comparative method [37]. Special attention was paid to disconfirming evidence and outliers in data coding, as appropriate given the modest size of the data set, as well as elements of frequency, extensiveness, and intensity within the data. Ideas or phenomena were initially identified and flagged to generate a listing of internally consistent, discrete categories (i.e., open coding), followed by fractured and reassembled (axial coding) categories by making connections between categories and subcategories to reflect emerging themes and patterns.

Categories were then integrated to form grounded theory using selective categorization to clarify concepts and to allow for response interpretations, conclusions and event potentially taxonomy development associated with critical features of a "global engineer". Frequency distribution of the coded and categorized data was obtained. The intent of this intensive qualitative analysis was to identify patterns, make comparisons, and contrast one transcript of data with another in preparation for Round two of the study. For each question, three researchers separately coded the data and met to discuss results and recode where necessary.

4.0 Results of Round 1 Delphi

<u>4.1 Question 1:</u> Using the qualitative categorization and coding of the data described above two primary, broad areas of categorization emerged. These two areas were also aligned with relevant literature from engineering and international education research. The first broad area of categorization was the appearances of both technical and professional skills of globally prepared engineers that are evocative of the enunciated ABET outcomes. A second broad area was the

need for cross-cultural knowledge and skills that propels beyond the ABET related outcomes. These two categorization areas are described in detail below.

An initial finding indicates that professional skills were quoted by 17 of 18 (94.4%) respondents as an essential attribute of becoming a global engineer. The data indicates that although standard engineering technical competencies or “hard” skills are important, non-technical professional skills were a focus of the discussion among the overwhelming majority of participants. Professional skills noted in the responses include effective interpersonal communication and teamwork, with morphing responses into coded subcategories of: cultural, political, and religious awareness, as well as value-based traits of open-mindedness.

Twelve of 18 (66.6%) respondents indicated the importance of having proficiency in at least one foreign language as an important skill to succeed in a global professional environment. Eleven of 18 (61.1%) participants noted cross/inter-cultural communication as a critical quality of becoming a globally prepared engineer. Several responses referenced the importance of being aware of one’s own cultural perspective, being curious, keeping abreast of world news/events and integrated thinking. One respondent stated, “I don't think that the question of ‘globally prepared engineer’ is about technical acumen, our U.S. trained engineers compete adequately from a technical point of view with Canadian, Australian, European and Asian engineers. Where they fall short is their longer learning curve in terms of cultural awareness and adaptation to a new environment, geography, and culture.” Importantly, 12 (66.6%) participants referenced fundamental engineering knowledge and competence as a required skill.

One important finding associated with this round of data is that the identified professional skills were not denoted by the level of importance nor by the stages at which attributes were essential to the preparation, performance, and employability of global engineers. Engineering “technical skills” that respondents described included foundational knowledge in engineering, science and mathematics fundamentals and high-level problem solving involving scientific knowledge from multiple disciplines. Table 2 provides a summarized listing of the knowledge and professional skills offered by the SMEs. This listing is not ordinal with regard to level of importance.

Table 2. “New” Knowledge, Professional Skills, and Values Generated from Round 1

Knowledge, Skills, Attitudes and Values
• Foundational knowledge in engineering , science, and mathematics fundamentals
• Awareness of local/regional differences in technical standards and regulations
• Global engineering practices
• Knowledge of world geography
• Knowledge of the history of engineering in various regions of the world
• Technical business practices infused with engineering (i.e., supply chain type issues)
• Ability to understand global markets, business, politics, and trade
• Proficiency in another language
• Basic communication skills (basic language; communicative)
• Knowledge of social/cultural/political/context for engineering problems
• Cultural awareness (awareness of how national differences are important in defining and solving technical problems)
• Ability to use technology information resources to solve problems
• Mental Agility/Flexibility
• Ability to work well with others
• Integrated thinking

Knowledge, Skills, Attitudes and Values
• Ability to interact with engineers from different cultures • Cross cultural communication (intercultural communication skills; strategies; comparative analysis) • Problem solving involving scientific knowledge from multiple disciplines being applied to non-US centered problems (not just problem solving; it's why we need the engineers; understanding of cross cultural similarities and differences in practice; ability to adapt to a project to local circumstances) • World view (understanding impacts of global connectedness) • International professionalism (ability to articulate global engineering practices in general and how their career as a future engineer impacts engineering practices globally) • Curiosity • Self-cultural awareness (aware of one's own cultural perspective; ethno-relativeness – being in one's shoes)

The frequency distribution in the responses (described above) suggests that the skills broadly identified as "soft" have been indicated by respondents as a distinguishing feature of a globally prepared engineer. As noted by Del Vitto (2008) [38], these skills reflect changes in the nature of engineering practice, ranging from greater teamwork, the ability to function in multi-national companies to cultural awareness, knowledge of a foreign language, and world geography. This finding is consistent with research claiming that the most essential upgrading of engineering education is less a deepening of technical skill than it is imparting new cross-cultural skills [39].

Although the ability to speak a foreign language has also been identified in the Delphi round one as important, (along with communication skills), results are mixed as to degree of language mastery versus the ability to communicate with others to solve engineering problems in a global context. For example, one respondent noted, "Language skills don't necessarily mean communication is good and accurate – cultural awareness is the most important element of communication." Yet another respondent noted that (paraphrased) ideally a global engineer needs to know a second language but if this is not an option, he/she should have intercultural communication skills, which are absolutely essential.

Delphi round one participants agreed that strengthened by the ability to speak a foreign language, cross-cultural communication skills "allow engineers to engage in-depth with colleagues from around the world in their own discipline and beyond." Further, the respondents indicated that a globally prepared engineer should be more adept than ever before at "communicating" with those from different cultures. Additionally, the respondents typically hypothesized that although technical strength is required, at the "core" has become the ability "to participate in the creation of a common global culture." As one of the respondents stated, "There is a need to move beyond an appreciation and respect for differences to synergistic global collaboration to create a culture of success within globally operating teams." Thus, effective cross-cultural communication emerged as an essential component, enabling engineering candidates to span any boundaries.

It is evident from the responses that the boundaries that globally prepared engineers must span are not those within and between engineering disciplines. One respondent noted, "They (students) need to look outside the walls of their university, their community, with the U.S. This view must extend to a global scale, meaning they should have knowledge and be able to articulate global engineering practices not only in their home state or area, but globally." S/he added that the ability to interact with engineers from other cultures is critically important.

4.2 Question 2: The process of analyzing the responses related to the most effective types of learning experiences followed a similar approach to that of the first question. It was evident from the coding that SMEs focused on five areas of effective types of learning experiences in their responses: curricular abroad, curricular in country or on campus, career/engineering in-field related, non-school/non-career related, and support structures.

From the perspective of abroad curricular experiences, nine of 18 SMEs (50%) mentioned having students engaging in a long term study abroad program. Another four respondents indicated immersion (with language immersion) programs that require direct enrollment would be effective. Of the abroad curricular experiences that were noted as effective, five SMEs highlighted long term study abroad as most effective; and three indicated that faculty led programs or short term programs were effective.

Regarding curricular in-country or on-campus experiences, SMEs provided a host of different opportunities in their responses. These included team projects with some type of multiculturalism, working on international teams, having teams be constructed in a diverse manner, conducting senior projects such that there is global significance, and introducing distance learning technologies to enable cross country-cross cultural interaction among students. There were eleven responses of this type. Another theme that emerged as effective experience was to introduce global awareness into the curriculum. Ideas in this theme included: adding 'exposure' elements to the engineering curriculum, incorporating a class in global engineering practices, and having students take liberal arts coursework so that they were exposed to other countries. Few respondents noted the importance of global engineering industry representatives coming to campus to network with students or having students attend presentations that industry personnel could provide. A few SMEs noted the value of taking a foreign language (five of 18 responses, two of which indicated that this was "most" effective), as well as taking MOOC-like courses with activities with persons from another country (two of 18 responses). There was also a mention of student chapters of international professional societies.

Career-focused engineering experiences were highlighted as being most effective. Specifically, 13 SMEs (72%) indicated that internships or co-ops were effective experiences. A few variations of internships were noted which included state-side internships with a company that had a global foot print (two responses), taking short work-related trips abroad (one response) or working alongside an individual from another country as part of the internship (two responses). Three responses mentioned conducting research in a foreign country or on a project with significant social impacts for promoting global competence. Likewise, there were five responses that included service learning and abroad projects (e.g., Engineers without Borders) as effective.

There were only two non-academic/non-career related responses (mission trip, tourism) noted by the SMEs. A few SMEs commented on the value of tour type explorations while studying abroad. With regard to support services, several SMEs commented on the value of having pre-departure preparatory programs whereby individuals can learn more about the country they are going to as well as practice their communication skills (seven responses). Another support service lauded by the SMEs was the value of placement services and company partnerships that focus on global internships (three of 18 responses).

In summary, from the results of this first round of the Delphi study, it became clear that the quality of the overall learning experience for engineering students is predicated not only the experience itself, but also on particular programmatic elements. Specifically, five elements of programmatic effectiveness were identified. First, although SMEs differ on what the term "long" indicates with regard to study abroad experiences, the duration of the learning experience is important. Several respondents indicated that student learning was influenced by the length of time s/he spent in another country. However, the minimum length of time that a student should spend in another country for an experience to make them globally prepared seemed to differ greatly amongst the SMEs. Second, the respondents indicated that multiple different experiences were needed for global preparedness. The degree to which the experience is related to or part of the curriculum appeared to be a third element. Fourth, the relativeness of the experience to the student's engineering field also resonated as an important experiential factor in preparing engineers. Finally, many respondents felt that the learning experience should take the student "out of his/her comfort zone". This was specifically noted by five of the 18 SMEs.

5.0 Discussion and Future Work

More than 430,000 students are enrolled in U.S. engineering programs, producing close to 70,000 B.S. engineering graduates annually [40]. An increasing percentage of graduates are employed in international environments. Further, the demand for globally competent engineers will continue to increase; faculty and administrators will need to offer opportunities to acquire such skills, knowledge, and mindset. Now more than ever, it is important for us to identify those learning outcomes and experiences for engineering education purposes. This Delphi study, when complete, will provide a working taxonomy and organizing framework for international engineering education for engineering educators and the community.

This first round of our Delphi provided indicators of learning outcomes that prepare engineers to be globally competent and also provided an in-depth listing of potential learning experiences that have effectiveness. These data indicated that a culminating learning outcome should be that engineering graduates possess the ability to problem solve using scientific knowledge from multiple disciplines that can applied to non-US centric challenges. In addition, the results of the round one Delphi revealed the importance of understanding the cross cultural similarities and difference in practice. Respondents noted that globally prepared engineers must be able to adapt a project to local circumstances to be effective. Finally, the SMEs noted that the next generation engineering graduate must have a world view to understand the impacts of global connectedness. From this study, there are a multitude of experiences by which these ultimate outcomes can be achieved; however, the quality of the experiences is a function of a mixture of factors.

Moving forward, for the second round of our Delphi study, we ask SMEs to group the learning outcomes that they described in round one into the various categories representing knowledge, skills and values. In addition, for the identified programmatic elements, we request that SMEs further define and articulate the elements and rate their preferences. Finally, for the various experiences, SMEs will rate their preferences to establish initial priorities for experience effectiveness. At the time of submission of this draft paper, we are collecting such information.

6.0 Acknowledgements

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