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Assessing the Spectrum of International Undergraduate Engineering Educational Experiences

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Assessing the Spectrum of International Undergraduate Engineering Educational Experiences: Three Studies

Abstract

International experiences are viewed as important components of undergraduate engineering education. Yet little has been done to define global preparedness, specify alternatives for achieving it, or determine to what degree being globally prepared is the result of personal attributes, prior experiences (including pre-college), or specific educational experiences.

A collaboration of investigators from four universities (Pittsburgh, Southern California, Tulsa, and Clemson) are investigating how the broad spectrum of international experiences both in and outside of formal curricula impact engineering students' global preparedness. Now in its fourth year, we have conducted two primary studies and are engaging in our third. The first study was an extensive Delphi survey with subject matter experts. The second study consisted of a quantitative and qualitative analysis of students at our four institutions. The third study being initiated this spring is a much larger survey of engineering students at representative universities across the U.S.

For the second and third studies, we developed and tested a comprehensive survey instrument that captures demographics, experiences and a measure of each student's global preparedness and incorporates the nationally normed Global Perspective Inventory developed by Braskamp and colleagues. This is enabling us to identify changes in global awareness, knowledge and thinking over the course of the students' transition from incoming freshman to graduating senior. The resultant information and tools will provide insight to engineering administrators and faculty as they consider how to best prepare students for the global economy through three linked studies. This paper offers an overview of the progress to date of our NSF funded research initiative that investigates how the various internationally focused learning experiences within engineering (both curricular and co-curricular) impact students' global preparedness.

Introduction

[Sections Labelled "Introduction" and "Overview of the Work" are reprinted from the 2015 ASEE Poster Session Paper as they provide preliminary material for the reader.][1]

Engineering and education faculty from four universities have collaborated to conduct a research initiative that examines how the various international education opportunities, both curricular and co-curricular contribute to the global preparedness of engineering graduates. The initiative is funded in part by the National Science Foundation, which has concluded that "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."[2] 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 and scholars, who have also noted the impact of globalization and the implication for continued U.S. economic leadership.[3-5]

Hence, the purpose of our collaboration is to comprehensively study the various ways that we can better educate globally prepared graduates given an already crowded curriculum. Specifically, we aim to better understand how the various international experiences both in (curricular) and out (co-curricular) of formal coursework 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 . . ."[6] Yet, most evidence about how international experiences and education impact engineering students lacks empirical research to guide educational practices. It is only recently that such studies are beginning to appear.[7,8]

Engineering faculty have anecdotally recognized that students who participated in study abroad programs tend to develop such skills as problem solving, cross-cultural communication, and working effectively with culturally diverse teams. Living internationally, especially in a non-English speaking country, prepares students to not only take risks, but to adapt to new environments, develop a greater understanding of contemporary issues, and put engineering solutions in a global and social context.[9] However, further research is required to fully support, quantify, and generalize these findings beyond anecdotal accounts. Stated another way, there is general agreement among researchers and administrators that international engineering education experiences are beneficial to students, but we don't know empirically the extent that the various experiences contribute to global preparedness, nor do we even agree on what global preparedness is. These experiences are expensive both for the student and for the University that provides the experiences – how can we ensure students are getting an appropriate educational value for their money? How can these experiences be tailored to achieve educational value? How should we advise students based on the individual's background, prior global preparedness, and financial resources so that the experiences are most effective?

This research addresses two perceived gaps in engineering education: 1) the need for a systematic study of curricular and co-curricular offerings in international engineering education to determine the extent to which the various international academic and non-academic experiences impact the global preparedness of engineering students; 2) the identification of the key constructs that characterize a globally prepared engineering graduate. By addressing both gaps, 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 to date of a research endeavor that addresses these two concerns.

Overview of the Work

This project is being conducted by a multidisciplinary team from four universities. Its four major objectives are delineated into three separate, but interconnected studies (i.e., Delphi, mixed-methods, and cross-institutional) combined with a dissemination system, as shown in Figure 1. In carrying out this research, we are testing three primary 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 project will *provide the engineering community with a set of practices correlated with international learning, various student populations, and types of programs.* Each study is discussed and an overview of how each question is addressed follows. We draw upon a definition of engineering global preparedness that has emerged from our research. Specifically, an engineering student's global preparedness requires him or her to become aware of and able to contribute to a global engineering workforce and marketplace. [10-13]

Study One: Expert Developed Framework

The purpose of Study One 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 conducted a comprehensive Delphi study, identifying and then obtaining opinions from experts on the learning outcomes based on the initial set of attributes. 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) representing 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?*

Their responses were used to construct a questionnaire that participants completed in the second round. From the participants' second round responses, areas of consensus and divergence were identified and used for the third round, in which the 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 (see Figure 1) provides an organizing framework for international engineering education and illustrates the interrelationships among engineering global preparedness attributes and three other broad categories: intercultural

contextual knowledge, personal and professional qualities, and cross-cultural communication skills and strategies. The outcomes from this study were used to produce a model of global engineering preparedness, which helped to provide the basis for a student background instrument that was employed in Study Two, as well as provided a means to determine how certain outcomes were achieved from students' international and global experiences.

Figure 1. Overview of the Research Agenda

Study Two: Mixed Methods Experiment

This study uses a mixed-methods quasi-experimental design to measure the learning outcomes identified in Study One. Learning outcomes are obtained through a mapping of the constructs with the two instruments' (EGPI and GPI) scales discussed 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)*[13]. The GPI has been administered at over 150 institutions; over 100,000 students, staff, and faculty have completed the GPI since its development in 2008[14]. The instrument draws on the work of Kegan, who argued that as people grow, they are engaged in meaning making[15]. It identifies three major domains of human development and associated questions, as delineated in Table 1.

Table 1: GPI Sample Items by Selected Subscales/Constructs

Subcale/Construct	Sample Index Item
Cognitive Knowing	I take into account different perspectives before drawing conclusions about the world around me.
Intrapersonal Identity	I put my beliefs into action by standing up for my principles.
Intrapersonal Affect	I am sensitive to those who are discriminated against.
Interpersonal Social Interaction	I frequently interact with people from a race/ethnic group different from my own.

The first domain is 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. The second domain is intrapersonal. It 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. Finally, the third domain is interpersonal social interaction. This domain asks "How do I relate to others?"; and 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.[16,17] It utilizes four subscales, as provided in Table 2, each of which have been validated using item response theory[18] and extensively tested for reliability.

The first subscale is *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. The second subscale is *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

methodologies and approach. *Engineering Global-centrism* is the third subscale. 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 one's ability to make sound judgements based on global needs in which engineering and associated technologies can have impact on global improvement. Finally, *Global Engineering Community Connectedness* is the last subscale. This subscale 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.

Table 2: EGPI Sample Items by Selected Subscales/Constructs

Subcale/Construct	Sample Index Item
Engineering Ethics & Humanitarian Values	Engineers in my country have a moral obligation to share their engineering knowledge with the less fortunate people of the world.
Global Engineering Efficacy	I believe that my personal decisions and the way that I implement them in my work activities can affect the welfare of others and what happens on a global level.
Engineering 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 in our workplaces.

An accompanying background survey was developed to identify those underlying student characteristics and the student's respective international/intercultural experiences contributed most to the individual's global preparedness as identified in Study One. The resultant background survey instrument consisted 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 items also provided independent predictor variables to help explain the results of the outcome instruments (EGPI and GPI). Samples (from each of the four partner institutions) of senior engineering students, each of whom had engaged in an at least one international experience were invited to complete the set of instruments (EGPI, GPI, and background survey). In addition to sampling seniors with international experiences, each campus also recruited a comparison set of senior engineering students who had not had an academic-based international experience, and a third sample of incoming freshmen, the former serving as a comparison group and the latter providing an institutional baseline.

After initially analyzing the results of the EGPI and the GPI, a subset of students were invited to participate in a follow-up interview of 20-30 minutes. Specifically, students at each institution who "scored" high on the outcome instruments (EGPI and GPI) were interviewed. The primary purpose of these follow-up interviews was to further tease out the underlying reasons for how these students' achieved relatively high levels of global preparedness. The following overarching

questions framed the interviews: “Why did you choose to study abroad and/or pursue an international experience?”, “Did these experience change the way you think about engineering?”, and “Did these experiences affect your thinking about the cultural relevance of engineering?” A set of probes based on the constructs of the two instruments and background survey helped to facilitate the overarching questions.

Study Three: Cross Institutional Study

Parkinson has identified 24 exemplar engineering schools that promote international education.[19] In Study Three (implemented in spring 2016) the hypotheses will be further tested by inviting a representative sample of 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. The purpose of the third study is to further test and explore the three 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 (and will be developing) to cultivate an influential group of users for distributing 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. In this manner we anticipate obtaining a more comprehensive picture of the various international educational experiences provided by U.S. engineering schools. At the completion of Study Three we will have a well-defined framework, having brought additional schools into the project. Using data obtained from these schools as described above, we will have constructed models, validated through interviews, that will better enable us to identify those factors, including various pedagogical approaches and formal and informal educational formats 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 internet to determine the global opportunities that each U.S. engineering school offers its undergraduates, including the range of study abroad experiences, co-op and internship opportunities, and service learning experiences through active chapters of organizations such as Engineers without Borders and Engineers for a Sustainable World. The platform will go ‘live’ early spring 2016.

Investigations and Lessons Learned Over the Past Year

We have completed Study One and have finished our data collection and initial analysis for Study Two. Further, we have fully invited and are now initiating our Study Three. This section provides a summary of new work conducted and the lessons learned during this past year. We do not report on Study One here as it is now completed and has been reported on via prior ASEE conference proceedings and a journal paper is to be submitted in the near future.

Study Two: Development of a Framework to Code Motivations and Changed Behaviors as a Result of International Experiences.

For the qualitative portion of Study Two, 58 interviews were conducted across the four collaborating institutions. The interviews were, on average, 30 minutes long; however, some interviews went much longer. Prior to developing the interview protocol, during the summer 2013, the team developed an initial framework for hypothesizing the motivations of students, their experiences and reflections and the potential relationship to the outcomes. From this framework an interview protocol was developed and piloted; and the framework was corroborated with the literature. The finalized framework, developed this past year, was loosely adapted from Prochaska et. al Trans-theoretical Model of Change,[20] as well as seminal work by Jackson et al[21] on social risk taking and Schon's work involving the reflective practitioner.[22] Figure 2 provides an overview of the theoretical framework for the interviews and guided protocol for coding the responses.

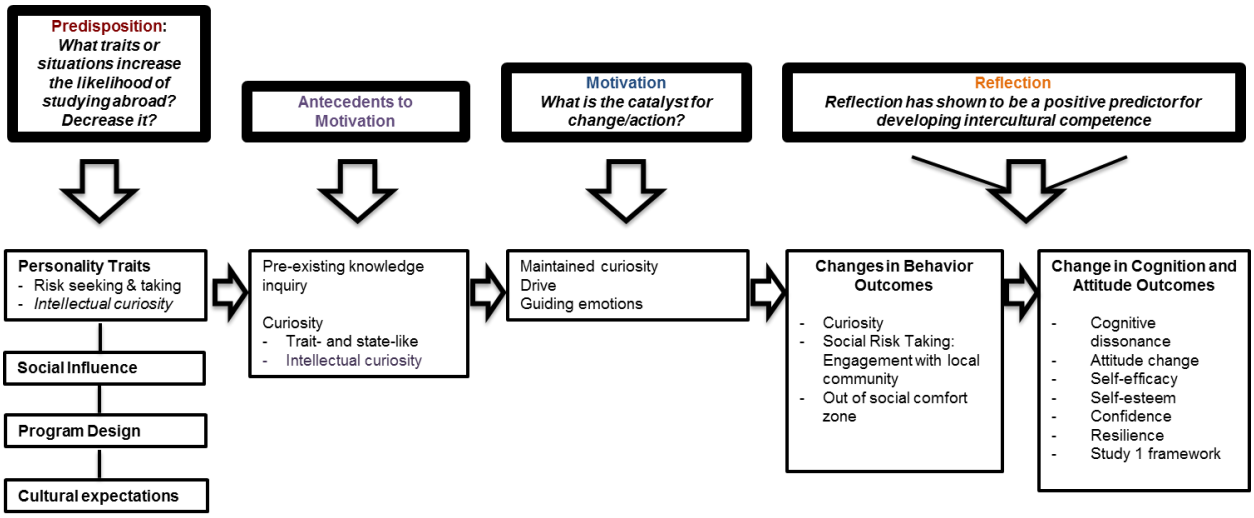

Figure 2. Theoretical Framework for Interviews and Coding Protocol

An inductive coding protocol was utilized to further refine definitions while allowing for additional analytical themes to emerge. The preliminary codes consisted of the type of international experience and structure, motivation, openness to experience, and degree of reflection. The transcripts were then coded according to a final schema by multiple research team members to ensure inter-rater reliability, and arbitrated where necessary. In all, the coding protocol consisted of six primary categories and a total of 31 sub-codes. Given the number of transcripts and coding protocols, some scholars have adopted a ''negotiated agreement'' approach for assessing intercoder reliability where two or more researchers code a transcript, compare codings, and then discuss their disagreements in an effort to reconcile them and arrive at a final version in which as many discrepancies as possible have been resolved.[23] The first round of coding the 58 transcripts has been completed.

Study Two: Quantitative Analysis – Our Freshmen are Quite Globally Prepared!

To better prepare for Study Three, we administered the GPI to *all* entering freshmen at the Swanson School of Engineering in Fall 2015. As discussed, the GPI consists of three scales, each of which consists of two subscales. However, these subscales are based on two different holistic human development perspectives that frame the GPI: *the theory of cultural development* and *intercultural communication theory*. Because of the large amount of data, we decided for our

initial analysis to aggregate the scales based on their underlying theory; i.e., cultural development and communication. Once significant differences were identified, then we were able to drill deeper into the subscales on follow-up students.

We were surprised to learn that 70% of our responding freshmen possessed a U.S. passport. The large majority (73%) had both parents and at least one grandparent born in the U.S.. The large majority (70%) were raised in a suburban environment, compared to 12% in an urban environment, 13% in a small town, and 5% in a rural setting. These were not first-generation students; only 6% had parents with just a high school education; another 5% reached the associate degree level in contrast to 35% at the BS/BA level, 37% with an MS/MA degree, and 17% with a doctorate degree. Over a fourth of the students (27%) indicated they could converse in a second language and 21% indicated that they would be comfortable taking a course in a second language.

Having learned that 70% of our incoming students possessed a U.S. passport, we were motivated to investigate the relationship between their international experiences prior to college and their global preparedness levels. The average Cultural Development (CD) and Intercultural Communication (IC) levels for all entering students were 3.66 and 3.61, respectively, compared to the freshmen norms given by Braskamp et al[24] of 3.75 and 3.71, respectively (which most likely were obtained during the first year rather than prior to beginning it). However, for those students who entered with no international experience, the respective CD and IC levels dropped to 3.57 and 3.47. In contrast, those freshmen that had some form of international experience rose to 3.70 and 3.67, respectively, clearly demonstrating a substantial difference between the two cohorts.

For a student to be classified as having "no international experiences," one of several scenarios applied. The student must have checked the "no international experiences" option, provided no response to the international experiences question, or selected only the second language course experience, but indicated no fluency in the second language; i.e., not able to carry on a conversation in the language nor take a course with instruction in that language. Conversely, students who indicated having had at least one international experience or indicated proficiency in a second language were classified as having had an international experience. This enabled us to further break down the students in terms of those whose international experience was travel based versus not (4.5%). Interestingly, the Cultural Development GPI level was slightly higher for the no travel group compared to the travel group – 3.73 to 3.70, while the Intercultural Communication level was substantially lower – 3.57 to 3.68. We further divided the two categories of no international experience and international travel experience by demographic factor. Students who traveled had higher GPI levels for both Cultural Development and Intercultural Communication. Note that these differences are especially large for the Intercultural Communication level for all categories examined.

We also asked our graduating Fall 2015 seniors to complete the instrument. Because seniors graduate in December, May and August, we will not have a complete set of data until the end of summer 2016. Here we report on the first set of graduating seniors. For the seniors, we included an additional level of detail in our analysis in order to identify whether the international experiences (if any) had occurred prior to college *only*, during college *only*, or prior to as well as during college. We received completed surveys from 75% of the graduating seniors; the respective CD and IC levels were 3.59 and 3.57, which surprisingly is well lower than the

respective levels for entering freshmen of 3.66 and 3.61 respectively. They are also substantially less than the norms reported by Braskamp, et al[25] for seniors of 3.84 and 3.72. It should be noted that international activities are strongly promoted within the Swanson School of Engineering - 67% - of those seniors completing the instrument were classified as having had an international experience. How do those graduating seniors with an international experience compare to those without one? Here the differences are quite striking – those with some form of international experience had GPI levels of 3.64 and 3.61, or almost identical to the undifferentiated entering freshmen. In comparison, those with no international experience had levels substantially lower at 3.49 and 3.48. Recall the levels for freshmen with no experience were 3.57 and 3.47 respectively. Seniors whose only international experience occurred pre-college had respective scores of 3.60 and 3.57 compared to freshmen entering with international experience of 3.70 and 3.67 respectively.

This potentially suggests that in the absence of no international experience during the college years, our graduating engineering seniors actually may exhibit a decline in their global perspectives. Consider those students who only had an international travel experience during their college years. The GPI levels are 3.56 and 3.57 or slightly less than that achieved by those who had their international experiences pre-college only. However, for those students who have had travel experiences both pre-college and during college, the GPI levels rise to 3.70 and 3.63 respectively.

Given these results at one institution, it becomes clear that teasing out increases in global preparedness as a function of when experiences occurred is a difficult issues as we move into the larger cross-institutional study.

Study Three – Cross Institutional Study

From the study two analysis, a shorter and more precise instrument was developed for the cross institutional study. Over the summer of 2015, the research team reviewed results of the four institution study to eliminate questionnaire items that were deemed unimportant to the research questions and theoretical framework or were found not to be significant. The resulting instrument was then piloted with students during the late summer and was found to take approximately 7-9 minutes to complete depending on the number of experiences a respondent had. The instrument consists of seven background questions of the student and three educational questions. The instrument then asks students to take the GPI, which consists of 35 items. Following the GPI, students were asked three targeted questions on the subject's international travel background; and depending on students' international experiences, the individuals answer seven questions related to the particular experiences they have had.

While the shorter survey was being designed, a campaign was conducted to elicit engineering schools from across the U.S. who have either established international programs for their engineering students or have recently started international programs as part of their curricular efforts. In all, 14 engineering schools obtained permission from their institution to engage in this research study.

During the spring 2016 term, we will be collecting 200 subjects from each institution (30 freshmen as a baseline, 110 seniors with an international experience, and 60 seniors without an international experience). In all, we hope to obtain a total of 2,800 questionnaires to analyze the

impact of international experiences engineering students engage in on their global preparedness as a function of the GPI.

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