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Measuring Engineering Students' Ability to Thrive in Diverse and Global Environments

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Abstract

Engineering programs, professional associations, and industry stakeholders emphasize the importance of preparing graduates for an increasingly global, rapidly changing environment. Although there has been increased attention to prepare undergraduates for a global engineering profession, there are challenges associated with measuring how cultural programs and experiences contribute to positive changes in students' abilities to work and thrive in diverse environments. Global competency can be defined broadly as "having an open mind while actively seeking to understand cultural norms and expectations of others, leveraging this gained knowledge to interact, communicate and work effectively outside one's environment"[1]. Measuring global competency levels before and after participation in cultural programs may therefore be a potentially effective method for measuring changes in students' ability to work in a global environment. Currently, studies on engineering students' baseline global competency levels are few at the undergraduate level. This research fills this gap, proposing a conceptual model of the factors that influence global competency levels, and also identifies the baseline levels of global competency for benchmarking. The resulting conceptual model and global competency measures will be useful toward larger scale inquiries to evaluate how participation in study abroad programs, international experiences, culturally-relevant curricula, and other related activities can contribute to changes in students' ability to work in diverse environments.

The Miville-Guzman Universality-Diversity Scale short form (MGUDS-S) measures the "universe-diverse orientation" construct, which "reflects an attitude of awareness of both the similarities and differences that exist among people"[2]. Higher MGUDS-S scores have been associated with a relative positive attitude toward others and the "simultaneous appreciation of both the similarities and differences that exist between oneself and others." Therefore, MGUDS-S is used here as a proxy for students' global competency levels in our conceptual model. Based on ordinary least squares regression models using data from 1,461 engineering freshmen, significant differences between MGUDS-S scores were identified. Female students scored higher than their male counterparts, while international students scored higher than domestic students. Among domestic engineering students, gender and ethnicity are associated with differences in MGUDS-S scores. These findings are consistent with results from previous studies, and suggest that women and underrepresented minority students, as well as international students, may receive higher scores since they may be more likely to interact with others from different backgrounds. These findings contribute to a burgeoning line of scientific inquiry lending support to programs that promote student travel abroad experiences and increased interactions between diverse groups of students. This research also has broad implications for providing information to academic institutions and key stakeholders to develop strategies toward the professional formation of engineers who can engage in an increasingly globalized environment.

Introduction

Global competency, defined as the ability to work with people from different cultural backgrounds has become a desired characteristic of 21st century professionals. Being globally competent implies understanding of other cultural norms and expectations and the ability to communicate effectively across cultures. Engineers are expected to solve problems and design products in an increasingly global setting; consequently being globally competent is critical to the engineering profession. Therefore, it is increasingly important for engineering educators to identify and promote strategies to enhance global competence abilities among their students.

Multiple authorities in engineering education have made a call for the advancement of engineering as a globally competent field. The National Academy of Engineering, for example, have stated in their vision of "The Engineer of 2020" that engineering activities should be framed in the context of rapidly moving technological changes, global interconnection of resources, and an increasingly diverse and multidisciplinary population of individuals involved in or affected by engineering developments. Among the NAE aspirations for the engineering field is "a future where engineers are prepared to adapt to changes in global forces and trends and to ethically assist the world in creating a balance in the standard of living for developing and developed countries alike"[3]. This vision reflects the need to embrace global competencies framed within ethical considerations, where technological development is advanced hand in hand with justice in a global setting. Furthermore, the Accreditation Board for Engineering and Technology (ABET) also includes an understanding of the global context among the requirements in the standards for the preparation of future engineers. According to ABET, graduates of accredited engineering programs must have "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context" and "a knowledge of contemporary issues" [4].

Some authors view the characteristics of the engineering profession aligning naturally with having an open mind to others' ways of thinking, i.e. being globally competent. Downey et al. [5], for example, base their rationale for the need of global competency among engineers on the premise that engineering problems are addressed differently by different people. These differences are more evident when considering different problem solving styles taught in different countries. Engineering problems are defined and solved in different ways in the U.S., Germany, and Japan, for example. However, the traditional engineering methods taught in the U.S. do not always incorporate lessons on how students can interact effectively with individuals with different perspectives. Despite the call to include global competency skills in the tool-set of engineering students by government and industry [6], and the thoughtful consideration of its definition and importance, there is evidence that efforts have not been enough to strengthen these capacities among engineering students. According to Downey et al. (2006), the different strategies used by universities to promote global competency skills can be been classified as: a) International enrollment, b) International project, c) International work Placement, d) International Field Trips and e) Integrated class experiences [5]. However, the proportion of students participating in different international experiences across universities is still small compared to the total number of students [7].

In order to design and promote new interventions to influence the levels of global competency among engineering students, we need to further examine which factors can impact this outcome effectively. Importantly, identifying where first-year engineering students are along the continuum of global competency levels can be useful in developing strategies to enhance this skill. Thus, we propose a conceptual model to identify the influence of students' demographic factors and the influence of previous travel experiences in generating first-year students' baseline levels of global competency.

Background

The Miville-Guzman Universality-Diversity Scale Short Form (MGUDS-S)

One construct that has been used to assess global competency is the Universal-Diverse Orientation (UDO) which "describes an attitude of awareness and acceptance of both the similarities and differences among people"[2]. This was a construct originally developed for measuring the ability of psychologists to work with patients from different backgrounds; however, it is also suitable for other settings. A scale that has been extensively tested and validated to measure UDO is the Miville-Guzman Universality-Diversity Scale (M-GUDS), a survey that contained 45 items in its original version. This instrument was later shortened into the MGUDS-S, evaluated and validated as a 15-item tool that could be more easily implemented[8].

The MGUDS-S has three main factors:

(1) ***Diversity of contact*****:** reflects the behavioral component of UDO and corresponds to the interest in participating in diverse and internationally focused activities of social and cultural nature;

(2) ***Relativistic Appreciation*****:** focuses on the cognitive component of UDO and consists of items that reflect appreciation of similarities and differences in people.

(3) ***Comfort with differences*****:** considers the evaluative and affective component of UDO, and reflects the comfort level with individuals from diverse backgrounds [8].

It is important to acknowledge that there are other tools to assess global competency through other constructs[9,10]. However, the MGUDS-S' high internal consistency and retest reliability (ranging from .85 to .88)[9] and its accessibility have made it a frequently used and cited tool to asses global competency, especially among engineering students [10–12]. Many studies have analyzed the level of global competency in engineering students using the MGUDS-S instrument. For example, Fuertes et al. [13] analyzed how the UDO correlates with areas of student development such as (a) attitudes toward seeking counseling for personal and vocational concerns, (b) attitudes towards diversity in college settings, and (c) students' academic self-confidence among a sample of first-year engineering students. They found that students with higher MGUDS-S scores also had a higher probability of seeking counseling and vocational help. In addition, higher MGUDS-S scores are positively correlated with better attitudes toward diversity and to higher levels of self-confidence.

Shen et al. examined engineering students' awareness and acceptance of cultural similarities and differences using MGUDS-S[14]. They addressed a) how the MGUDS-S scores varied among different populations of engineering students, considering also those in different types of global

engineering programs, and b) if there were significant differences in MGUDS-S scores between baseline populations of first year engineering students and students enrolled in international engineering programs. The mean MGUDS-S scores were consistently higher in all the three subscales for all the international programs considered. These results strengthen the evidence favoring the MGUDS-S tool as a sensitive tool able to detect differences among groups.

Jesiek et al. assessed cross-cultural competence by examining whether there were significant differences in openness to and appreciation of cultural diversity between students in global engineering programs compared to baseline groups of engineering students not participating in such programs[10]. Through the use of the MGUDS-S tool, Jesiek and his collaborators identified that there were significantly higher levels of openness to and appreciation of cultural diversity. They also found significant effects from demographic characteristics such as gender, i.e. female students had much larger gains from the international experiences compared to their male counterparts. Thus, due to its high internal consistency and test reliability, along with its documented use in higher education, we apply the MGUDS-S instrument to measure global competency in our study.

Methods

We designed a survey instrument that included the 15-item MGUDS-S survey and questions relevant to the variables described above (i.e., detailed information regarding trips outside of country of citizenship—purpose and duration of trip, proficiency in other languages, and demographic factors). The survey was administered to first-year engineering students at a large, Midwestern research-intensive institution in the fall of 2012. The response rate was 75.6% while the completion rate was 95.8% resulting in 1,461 valid student responses.

A conceptual model to examine global competency

We propose a conceptual model for the changes of global competency levels of engineering undergraduate students and how it is influenced by different factors through time. A conceptual model differs from the formal structures of hypothesis testing in the sense that it is exploratory in nature. That is, it looks to uncover any existing relationships between the considered variables, based either in theory or in empirical evidence, instead of testing the magnitude or direction of hypothesized relationships [15]. Our model proposes that students entering an engineering program may already have certain levels of global competency, and that these potential differences are critical in designing strategies and interventions at the college-level. In our model, these baseline levels are influenced by the students' background, i.e. student personal characteristics and students' previous experiences, such as intercultural experiences (travel abroad), and their proficiency in other languages.

Our conceptual model is shown in Figure 1. In this article, our examination focuses on students' backgrounds and their global competency levels in the first-year (denoted by the area within the dotted line in Fig. 1). We depict, however, the model expanded across time to show how college-level experiences can contribute to changes in global competency levels toward the formation of more globally-mind engineers. As part of this conceptual model, we propose that each student has his or her own trajectory in terms of changes in global competency—this is a function of individual background and pre-college experiences, and then the unique set of diversity-related

college-experiences in which he or she engages. Therefore, it is critical to take into account and disentangle the effects of time from the effects of participation in programs to better estimate the effects of global programs. While we do not extrapolate further in this paper regarding the college-level experiences, the set of activities and programs involved in the college experience box are varied, and can include study abroad, volunteering abroad, or learning other languages. Additionally, while we use the MGUDS-S tool as a proxy to measure global competency, the conceptual model can accommodate other validated instruments for measuring constructs reflecting global competence.

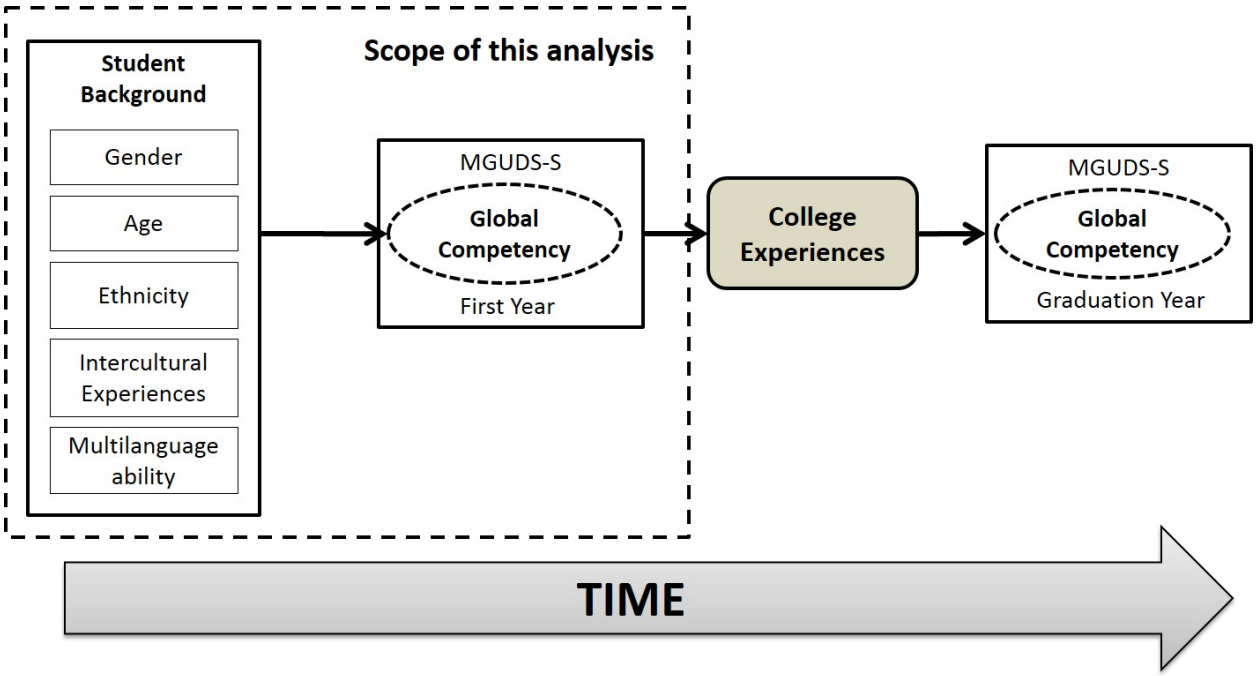

Fig. 1. Conceptual Model of Examining Global

Elements of the conceptual model

The variables considered in our conceptual model of global competency among undergraduate students are described below. These variables are also used in the Ordinary Least Square Regression (OLS) models.

Student demographic factors

- *Gender:* Male or Female.
- *Age:* Number of years.
- *Ethnicity:* White, Asian, or Underrepresented minority (URM) which include African American, Hispanic, Pacific Islander, Native American, multiracial, and other minorities.

Student previous experiences

- *Intercultural Experiences:* Dichotomous variable defined as whether the student has ever traveled abroad from their Country of Citizenship (COC).
- *Multilanguage abilities*: Dichotomous variable defined as whether the student has fluent proficiency in two or more languages.

Ordinary Least Squares Regression Models

To test the proposed conceptual model, we applied ordinary least square regression models to examine if there are significant factors that are associated with changes in the MGUDS-S scores. We generated four models to investigate global competency using the different factors of the MGUDS-S scores: (1) Diversity of contact, (2) Relativistic appreciation, (3) Comfort with differences, and (4) Total MGUDS-S score. We also conducted models separately for domestic and international students. Due to the potential relationship between the variables, we assessed multicollinearity in the models, and found no evidence of multicollinearity in any of the variables based on the variance inflation factor criteria (VIF<10). Due to the exploratory nature of this work, the significant level considered was $\alpha = 0.10$. All coefficients shown in the results tables are unstandardized.

Data

Descriptive Statistics

Table 1 decribes the characteristics of the 1,491 first-year students in the sample. The summary statistics are also categorized by domestic student (n=1,112) and international students (n=349). The quality of the received responses was verified considering: a) completion of MGUDS-S items, and b) consistency and viability of answers. After this process, there were 1,461 valid responses available for analysis.

Table 1. Description of Participants

Variables		Domestic (%)	International (%)	***Total***
Gender	Male	805 (72.4)	263 (75.4)	***1,068 (73.1)***
	Female	288 (25.9)	78 (22.4)	***366 (25.1)***
	Missing	19 (1.7)	8 (2.2)	***27 (1.8)***
Age	Mean	18.68	18.974	***18.75***
	SD	0.8857	1.1277	***0.9569***
	Range	17-28	15-25	***15-28***
	Missing	13	3	***16***
Ethnicity	White	923 (83)	16 (4.6)	***939 (64.3)***
	Asian	67 (6)	303 (86.8)	***370 (25.3)***
	URM	122 (11)	30 (8.6)	***152 (10.4)***
Ever Traveled outside COC	Yes	743 (66.8)	349 (100)	***1,092 (74.8)***
	No	368 (33.1)	0 (0)	***368(25.2)***
	Missing	1	0	***1(0)***
Ability in 2+ languages	Yes	117 (10.5)	283 (81.1)	***400 (27.4)***
	No	995 (89.5)	66 (18.9)	***1,061 (72.6)***
Total		***1,112 (76.1)***	***349 (23.9)***	***1,461 (100)***

Note: Quantities in parentheses denote percentages.

As shown in Table 1, the gender composition is consistent between the domestic and international subgroups with a percentage of males above 70 percent. The age of the participants ranged from 15 to 28 years overall, with international students being slightly older than domestic

students. The ethnic composition of domestic and international students is considerably different. Among domestic students, 83% indicated white, whereas 87% of international students indicated Asian. As expected, all of the international students had travel outside of their COC at least once. Meanwhile, 33% of domestic engineering students have not yet traveled outside of the United States. The multilingual ability of the domestic and international groups also differs with 81% of international students speaking 2 or more languages compared to only 10% of domestic students.

Pre-college travel experiences

We also examined the reasons and characteristics of students' pre-collegiate travel experiences. The reasons for travel were categorized into: a) study abroad, b) work/volunteer c) other (including vacation, relocation, family visits, etc.). Fig. 2 summarizes the number of trips respondents have taken outside of their country of residence and the reasons for travel for domestic students. Fig. 3 illustrates the same for international students. Among domestic students, 376 students have not yet traveled abroad and therefore are not included in the graph. Comparing figures 2 and 3, international students have a higher proportion of study abroad trips, while domestic students have a higher proportion of trips for "other" reasons. International students with 3 to 5 trips outside of their COC were the only students who reported travel for work/volunteer reasons.

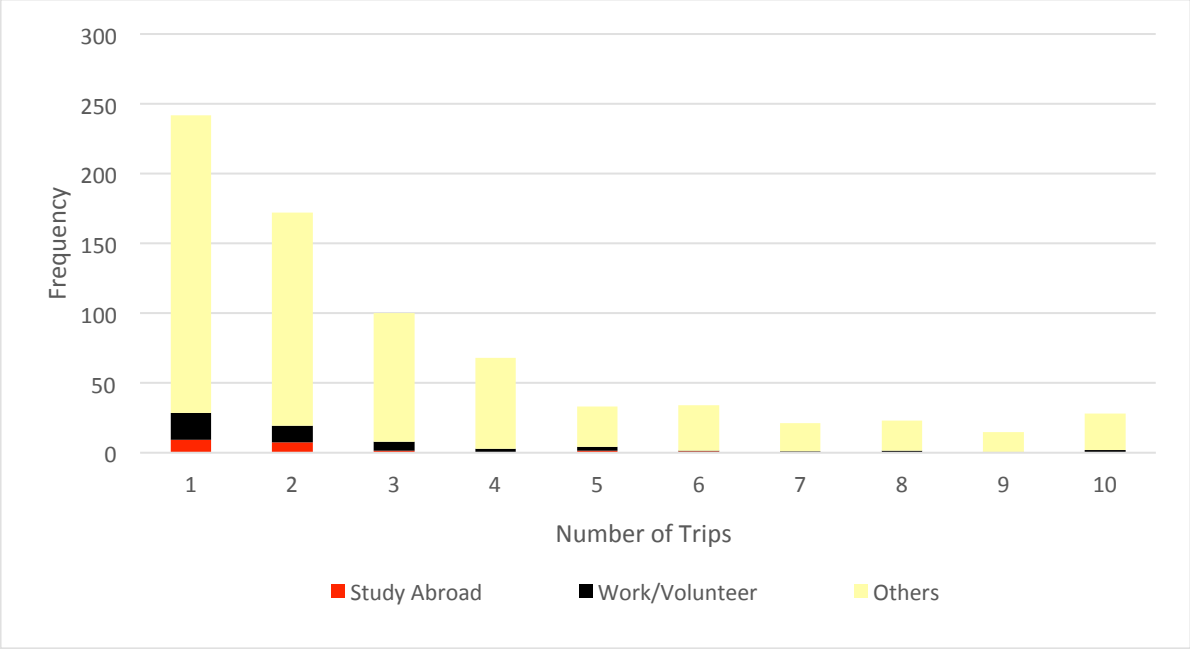

Fig. 2. Number and reasons for trips outside of the United States for domestic students.

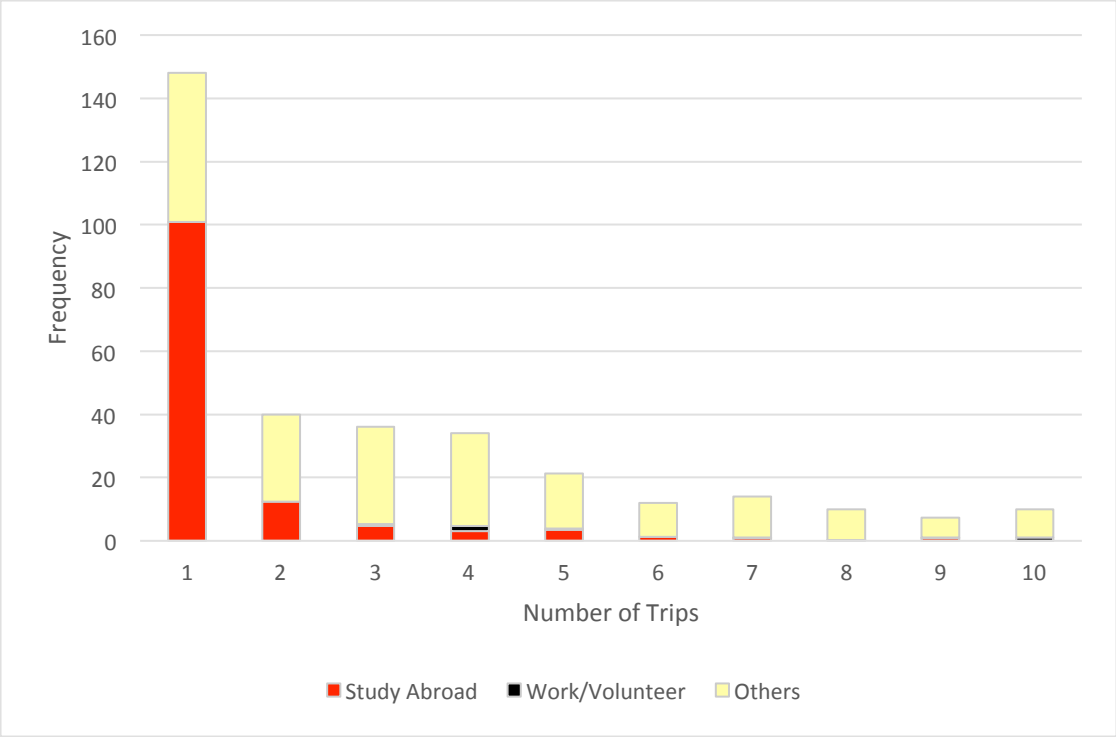

Fig. 3. Number and reasons for trips outside of country of citizenships for international students.

MGUDS-S Scores

To analyze the relationships between the MGUDS-S sub-scores and total score, we generated a scatterplot matrix (Fig. 4). The scatterplot matrix shows the relationships between the MGUDS-S total score and each of the sub-scores, as well as the relationships between each pair of sub-scores. Furthermore, the data is grouped by international status, where blue elements represent international students and red elements represent domestic students. As expected, the MGUDS-S total score is positively correlated with each of the sub-scales: diversity of contact, relativistic appreciation, and comfort with differences. However, the correlation shown between the different pairs of sub-scales varies, likely since each of the subscales measures different traits of the UDO [8]. Interestingly, the variation in correlation among the pairs of subscales appears to be influenced by the respondents' country of citizenship (U.S. domestic vs. international). For example, the *diversity of contact* and *relativistic appreciation* sub-scores are positively correlated among all the students (r=0.56); however, the strength of this relationship varies between domestic (r=0.53) and international (r=0.63) students. The relationship between *diversity of contact* and *comfort with differences* is relatively weak (r=0.29), but appears stronger when focusing only on domestic students (r=0.39). There is a similar relationship between *relativistic appreciation* and *comfort with differences* (r=0.23) when analyzed by subgroup (r=0.28 for domestic and r=0.18 for international students). These lower correlation levels indicate that even though respondents can reach high values in one sub-scale, it is possible that they can score lower in another MGUDS-S subscale at the same point in time.

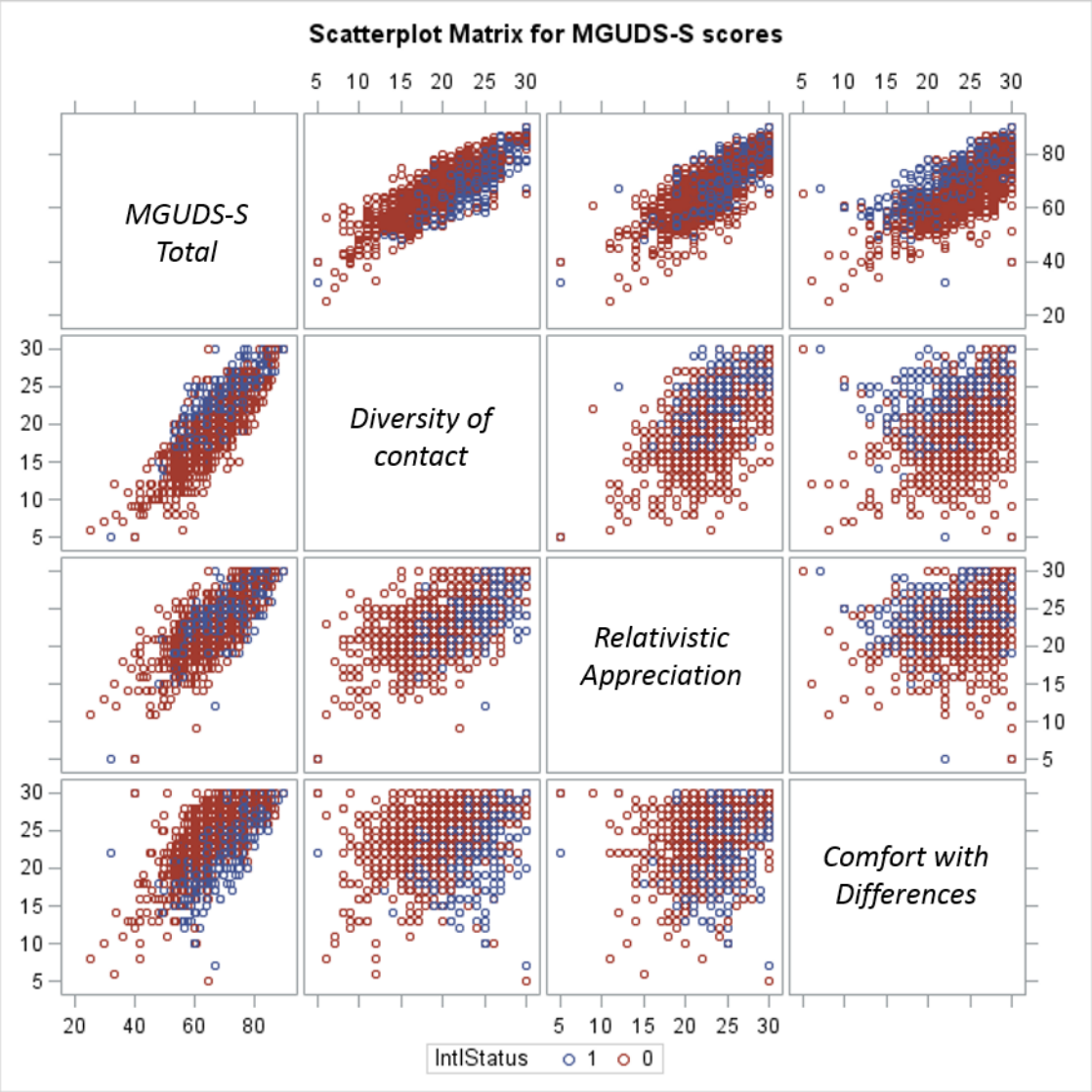

Fig. 4. Scatterplot matrix of the MGUDS-S subscale and total scores.

Table 2 reports descriptive statistics for the MGUDS-S subscale and total scores by student international status (domestic vs. international), whereas Table 3 reports similar MGUDS-S descriptive statistics by student gender. The mean MGUDS-S Total score is higher among international students (70.06 *SD*=8.73) compared to domestic students (66.2, *SD*=9.23), and the difference is statistically significant (p-value<0.01). Similarly, women scored higher (69.6, *SD*=9.06) than men (66.25, *SD*=9.19), and the difference is also statistically significant (p-value<0.01). These findings are consistent with previous work conducted by Miville et al.[2,16], and also suggest that women and underrepresented minority students, as well as international students, may score higher since they may be more likely to interact with others from different backgrounds.

Table 2. Descriptive statistics of MGUDS-S sub-scale and total score between domestic and international students.

		Diversity			Relativistic			Comfort			MGUDS-S Total		
	N	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Domestic	1112	19.28	4.41	5-30	22.71	3.55	5-30	24.2	3.89	5-30	66.2	9.23	25-90
International	349	23.15	3.66	5-30	23.99	3.39	5-30	22.91	4.43	7-30	70.06	8.73	32-90
Total	1461	20.2	4.55	5-30	23.01	3.55	5-30	23.9	4.06	5-30	67.12	9.27	25-90

Table 3. Descriptive statistics of MGUDS-S sub-scale and total score by student gender

		Diversity			Relativistic			Comfort			MGUDS-S Total		
	N	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Female	366	21.43	4.48	5-30	23.87	3.21	5-30	24.28	4.29	5-30	69.6	9.07	25-87
Male	1068	19.77	4.5	5-30	22.71	3.62	5-30	23.76	3.96	5-30	66.25	9.19	30-90
Total	1461	20.2	4.55	5-30	23.01	3.55	5-30	23.9	4.06	5-30	67.12	9.27	25-90

Results

OLS Regression Models: Domestic Students

Table 4 shows results from the OLS regression models for each of the MGUDS-S subscales and total scores among domestic students in their first year of engineering (n=1,079). The outcome for each of the subscales is measured on a scale of 5 to 30, whereas the total score can range from 15 to 90. The predictor variables are described in the methods section above, and include gender, age, ethnicity, travel experience, and fluency in more than one language. We found that gender is a significant factor for all the subscales and the total score. Everything else held constant, women score 3.73 points higher than men in the MGUDS-S total score. On the other hand, age was not a significant factor in any of the MGUDS-S subscales or total score.

The results regarding ethnicity are mixed. In the diversity of contact sub-score, Asian and URM students received higher scores than their counterparts. There is no significant difference among the groups on the *relativistic appreciation* sub-score. URM students showed a significant positive effect in the *comfort with difference* sub-score, and these significant associations remained present in the total score—Asian and URM students tend to have higher total MGUDS-S scores by approximately 4 points compared to their counterparts. Traveling abroad was significantly associated with higher *diversity of contact*, *comfort with difference,* and total MGUDS-S scores. Fluency in two or more languages had a significant positive relationship with the *relativistic appreciation* sub-score and remained significant at the 0.05 level in the total MGUDS-S score.

OLS Regression Models: International Students

Table 5 summarizes the results from the regression models using only data from international students (n=338). Since all of the international students have traveled abroad, this model does not include this variable. While gender is a significant factor in the total MGUDS-S score, it was only positively associated with the *diversity of contact* subscale, with women scoring 1.53 points

higher than their male counterparts. Age has a modest, but significant negative association with the *comfort with differences* subscale. Among international students, there is no difference between Asian, URM, and white students in the MGUDS-S subscales or total score. Although the effects of ethnicity are not significant, they showed different directions for different subscales, i.e. positive relationships with *diversity of contact* and *relativistic appreciation,* but negative relationship with *comfort with differences* and the total score. Ability in languages only showed to be relevant for the *diversity of contact* sub-score.

Table 4. Regression coefficients: Domestic Students

	Domestic Undergraduate Students MGUDS-S Subscales							
Variables	Diversity of Contact		Relativistic Appreciation		Comfort with Differences		Total	
	β	Se(β)	β	Se(β)	β	Se(β)	β	Se(β)
Female	1.84**	0.29	1.30**	0.24	0.59*	0.27	3.73**	0.62
Age	0.12	0.15	-0.07	0.12	-0.13	0.13	-0.08	0.31
Asian	2.55**	0.56	0.72	0.46	0.68	0.51	3.96**	1.17
URM	2.08**	0.43	0.69+	0.35	1.42**	0.39	4.19**	0.90
Ever Traveled outside COC	0.88**	0.28	0.22	0.23	0.77**	0.25	1.88**	0.58
Ability in 2+ languages	1.46	0.45	0.98**	0.38	-0.31	0.42	2.13*	0.96
Intercept	15.44**	2.74	23.31**	2.29	25.77**	2.52	64.52**	5.80
N	1,079		1,079		1,079		1,079	
R^2-adj	8.60%		10.88%		4.23%		2.51%	
F-statistic	22.94**		8.94**		5.62**		18.08**	

+ significant at the 0.10 level; * significant at the 0.05 level; ** significant at the 0.01 level

Table 5. Regression coefficients: International Students

	International Undergraduate Students MGUDS-S Subscales							
Variables	Diversity of Contact		Relativistic Appreciation		Comfort with Differences		Total	
	β	Se(β)	β	Se(β)	β	Se(β)	β	Se(β)
Female	1.53**	0.46	0.59	0.44	-0.13	0.54	1.98+	1.10
Age	-0.09	0.18	-0.004	0.17	-0.77**	0.21	-0.86*	0.42
Asian	0.03	0.93	1.06	0.89	-2.7+	1.09	-1.67	2.22
URM	0.55	1.12	0.76	1.07	-1.00	1.31	-0.31	2.67
Ability in 2+ languages	0.87+	0.50	0.14	0.48	-0.26	0.58	0.75	1.19
Intercept	23.79**	3.54	22.86**	3.38	40.3**	4.15	86.95**	8.43
N	338		338		338		338	
Adj R^2	2.71%		0.01%		6.20%		1.50%	
F-statistic	3.39**		1.45		6.27**		3.7**	

+ significant at the 0.10 level; * significant at the 0.05 level; ** significant at the 0.01 level

Discussion and Future Work

Consistent with previous studies, our results indicate that among domestic students, women and underrepresented minority students are more likely than their counterparts to have higher global competency scores as measured by the MGUDS-S[13,16]. Among international students, women are also more likely to score higher on the MGUDS-S compared to men. These global competency scores are measured during students' first semester in their engineering program and therefore likely reflect baseline scores stemming from individual demographic factors and pre-collegiate experiences with travel abroad and multilingual abilities. Our findings lend evidence to our conceptual model of the importance of taking into account pre-collegiate factors in determining potential changes and increases in students' global competency levels. Since global competency levels can vary across student subgroups and across the different MGUDS-S subscales (diversity of contact, relativistic appreciation, and comfort with differences), it is important to consider this variation when developing strategies for preparing engineering students to thrive in an increasingly diverse and global workforce. The many interventions to increase global competency (e.g., research abroad, diverse teaming experiences, learning multiple languages) during the undergraduate engineering program may have different effects on each of the subgroups and also may influence different factors of the Universal-Diverse Orientation (UDO) construct.

Although the data analyzed are limited to one institution and the MGUDS-S represents only one of the many ways that global competency can be measured, this study offers some insights regarding the effects of pre-collegiate experiences in students' global competency levels. Our future work will investigate individual changes in global competency levels as a function of interventions at the undergraduate level, such as research abroad experiences, engagement in diversity programs, etc. Since age was a significant factor among international students, we will also examine the potential relationship between age and global competency using data collected from engineering doctoral students. This study will be enhanced with interviews of both domestic and international graduate students to gain a richer understanding regarding students' perspectives about engaging in diverse environments and their academic travel experiences. Exploring which factors influence the global competency among students upon entry into and at the conclusion of their engineering programs can help key stakeholders design and further develop student experiences to maximize students' ability to work and thrive in diverse and global environments.

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