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Measuring the Relative Impact of International Experiences on Engineering Students: A Benchmarking Analysis*

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Engineering educators and higher education leadership believe those students who are able to work effectively with colleagues across national, cultural, and ethnic boundaries will be more prepared and successful post-graduation. Research has shown that international experiences have a positive impact on students' global perspectives. Unfortunately, engineering students' participation in said experiences is relatively low (historically), due to a variety of reasons such as lack of preparation, highly sequenced curricula, and lack of integration. Thus, engineering schools who are investing in internationalizing their programs need to determine whether these investments are producing their intended results and what experiences have the greatest impact. This study explores how engineering students utilize international experiences while in college and which experience types are most effective relative to global perspective development. Results from this study suggest that internships, co-ops, and technical research conducted abroad provide the largest impact to improving global perspectives while also being the least frequent type of experience. Further, the largest gains in global perspectives occurs after one international experience or by participating in a variety of experience types. This study supports a means by which global perspectives should be developed in engineering students—i.e., improving the global perspectives of an increasing diverse student population to what is empirically possible given the opportunities available to them, mediated by their upbringing and background. As institutions continue to invest time and resources into education abroad experiences, it is important to determine how students can get the most out of the available international opportunities, especially as students are presented with more and more options as to the types of activities and educational practices they can engage in during college.

Keywords: global competence; international programs; student backgrounds; internships

1. Introduction

The need for instilling global perspectives into engineering student populations has been highlighted by professional and educational engineering communities alike; [1] and they have urged engineering schools to prepare engineers for the global workforce [2–4]. Engineering programs are beginning to emphasize international education opportunities, investing substantial resources to increase participation, both curricular and co-curricular, with the expectation that students who participate in such experiences become more globally competent. This, along with increased enrollment in US engineering programs, increased enrollment of women and international partnerships and exchanges, has contributed to an increase in engineering participation in study abroad programs over the recent years [5–7]. In the 2016–2017 academic year, US students majoring in STEM fields made up 26% of all US study abroad students, a 44% increase in the last five years compared to a 17% increase for all US students [7]. While study abroad remains the most popular method to prepare students [8], engineering schools are beginning to develop a wide variety of international experiences, ranging from credit-bearing, globally focused courses to international internships and research projects. However, little empirical evidence has been collected to measure the impact of the various forms of international experiences. As engineering schools invest in global programming, research is needed to analyze how engineering students utilize international opportunities and explore program types that have the most impact on a student's global perspectives.

This exploratory study leverages ordinary least squares (OLS) regressions, correlation analyses, and Data Envelopment Analysis (DEA) to investigate how engineering students utilize international experiences in college and explore the relative efficiency of student's global perspective development as measured by the Global Perspective Inventory (GPI) [9]. DEA is a frontier estimation technique for measuring relative efficiencies of a homogenous set of decision making units (DMUs) having multiple inputs and outputs [10, 11]. The ability to handle multiple inputs and outputs makes DEA an attrac-

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tive choice of technique for measuring efficiency in an educational setting [12, 13] and has been used in a variety of different higher education applications [12–18]. The DMUs for the DEA model in this global engineering context are undergraduate engineering students, the inputs are the number and type of different international experiences that students have participated in, and the outputs are the scores on the GPI dimensions. DEA and regressions were used to explore the types of experiences senior engineering students participated in, the efficiency of students' global perspective development, the reasons for inefficiency in international experience engagement, and how efficiency compares against student subgroups. The following research questions are addressed:

1. What factors are related to the efficiency of global perspective development?
2. How can students make the best use of international experiences while in college?

2. Background

2.1 Global perspectives of engineering students

Engineering schools have attempted to instill in students the "global competency" skills necessary to successfully engage and compete in an increasingly diverse and interconnected world [19]. The final definition of global competence [8, 20], global perspectives [21], global preparedness [22], intercultural competence [23, 24], intercultural maturity [25], and the other various terms prevalent in the literature might be impossible due to disciplinary context and philosophical preferences [26]. Engineering global competency research has mostly involved describing attributes or skills deemed important for the global work environment [8, 27], while others have developed frameworks that operationally define globally competent engineers [28, 29].

Several assessment instruments are available to measure global competence and related constructs, such as Intercultural Development Inventory (IDI) [30], Miville-Guzman Universality-Diversity Scale [31], Engineering Global Preparedness Index (EGPI), and the Global Engineering Competency Scale (GECS) [32]. The output variables of this study leverage the work of Braskamp, Braskamp, and Engberg on global perspectives. Braskamp, citing King and Magolda, proposed three dimensions of learning and development of global perspectives: cognitive (knowing), intrapersonal (feeling), and interpersonal (behaving). This view of student development is holistic and integrative, as students must develop in all three dimensions if they are to become mature persons [25]. This theory is operationalized by the Global Perspectives Inventory (GPI) [9], a nationally normed and extensively tested instrument. Global perspectives involve three critical questions related to the cognitive, intrapersonal, and interpersonal domain: "How do I know?" "Who am I?" and "How do I relate?" A global perspective is defined to include the acquisition of knowledge, attitudes, and skills important to intercultural communication and the development of more complex epistemological processes, identities, and interpersonal relations [33–35]. The GPI includes 35 items and uses a 5-point Likert-type agreement scale. The GPI identifies three major dimensions of human development: Cognitive, Intrapersonal, and Interpersonal. Table 1 illustrates GPI sample items by selected dimension.

Higher education has emphasized global education as a piece of its strategic goals over the past decade. The National Academy of Engineers (NAE) letter Educating Engineers to Meet the Grand Challenges commits to providing students with "global and cross-cultural perspectives gained through experience that promote involvement with globally complex issues in unfamiliar environments, such as semester abroad [2]. A series of national report and studies, motivated by globalization, and even the new ABET criteria have challenged engineering programs to produce graduates who can "work effectively with colleagues across national, cultural, and ethnic boundaries". Though global competency can be achieved through a wide variety of programs (extracurricular, co-curricular, and curricular) [8, 36, 37], a myriad of barriers (perceived and otherwise) exist that make it more challenging for engineering students to participate

Table 1. GPI Sample Items by Selected Dimensions [9]

Dimension	Sample Index Item
Cognitive	• I take into account different perspectives before drawing conclusions about the world around me • I can discuss cultural differences from an informed perspective.
Intrapersonal	• I put my beliefs into action by standing up for my principles. • I am sensitive to those who are discriminated against.
Interpersonal	• I frequently interact with people from a race/ethnic group different from my own. • I think of my life in terms of giving back to society.

in an international experience by graduation [38]. This begs the question—if engineering students are limited in their ability to engage in international educational practices, which practices provide the largest impact in terms of global competency development?

2.2 High-impact educational practices

The Association of American Colleges and Universities (AAC&U) has called for higher education institutions to embrace essential learning outcomes for student success, which are designed to ensure that students gain knowledge, skills, capacities, and competences to engage locally and globally, to solve significant problems, and to interact with diverse others [39]. The AAC&U have named ten "high impact" educational practices based on research suggesting positive benefits to students. Included in this list of high impact practices are *diversity/global learning experiences*, along with other engineering relevant experiences such as internships, research, and capstone courses and projects. According to Kuh, these educational practices are effective because they require dedication from students; require students to communicate; expose students to diverse ideas and people with different backgrounds; provide students with assessment; enable students to apply their knowledge and skills outside of the classroom; and have a potential to change students' lives [40]. Diversity and global learning (e.g., study abroad) have been tied to numerous college outcomes including the development of intercultural competence [24]. Study abroad was a positive predictor for intercultural effectiveness and internships, capstone courses, and projects were positive predictors for inclination to inquire and lifelong learning [39]. Findings from Kilgo, Sheets, and Pascarella indicate that active and collaborative learning and undergraduate research were the most beneficial to students in relation to the essential learning outcomes. These findings suggest that not all educational practices have the same influence on student learning (including global perspectives) and that institutions should strive to provide students with opportunities to engage in high-impact practices. This study explores this further by investigating the impact internationally focused educational practice has on global perspective development.

3. The present study

3.1 Instrumentation and variables

Data for this study were drawn from a National Science Foundation (NSF) Research in Engineering Education (REE) project called *Assessing the Spectrum of International Engineering Education Experiences* (EEC-1160404). As part of this project, an instrument was administered to first-year and senior undergraduate engineering students across 14 participating U.S. universities that included the GPI, background questions, and questions related to prior international experiences.

Input Variables: The student background items included academic level, sex, ethnicity, parents' educational background, type of location where the student was raised (e.g., urban, suburban, rural or small town), college GPA and second language fluency. These variables were chosen based on prior research efforts and literature suggesting a relationship to global perspective development. The experiential items included the number and type of international experience students have previously engaged in and when the experiences were had (e.g., before college or during college). Due to the number of possible international experiences, these experiences were further grouped into more general learning experiences (Table 2) and categorized as curricular, co-curricular, or extracurricular in nature. The total number of experiences and the variety (i.e., different types of experiences) was also recorded. The final instrument took approximately seven to nine minutes to complete, dependent on the number of the students' international experiences. The Institutional Review Board at the research University approved this study (IRB #PRO015080172).

In addition to the grouping of experience types from the survey, students who marked 'Other' on the survey and wrote a description of their experience; and these were coded according to one of the seven experience types.

Output Variables: The items in the GPI address the following critical questions related to human development: How do I know? Who am I? How do I relate? [46, 47]. The *Cognitive* dimension of global perspective examines "epistemological processes used to evaluate and make meaning of different knowledge sources" [41] as well as the "acquisition of knowledge to enlarge one's understanding of cultural differences" [42, 43]. The *Intrapersonal* dimension emphasizes "how identity development parallels the process of acquiring greater intercultural sensitivity" [44] and how one integrates one's personal values into one's personhood and how one becomes aware of this process. The *Interpersonal* dimension reflects "the interdependent nature of a global society, emphasizing the need to interact across difference and make socially responsible commitments to local, national, and global communities" [25, 45]. Each GPI dimension contains subscales based on two different holistic human development perspectives: the theory of cultural

Table 2. International Experience Types Included in Study

International Experiences	Learning Type	Definition	Educational Type
Personal tourism.	Personal Tourism	Trips abroad that served little to no educational value (e.g., research conferences abroad, visiting friends, vacation).	Extracurricular
Second language course.	Second Language Course	Courses where the primary learning outcome related to second language fluency.	Curricular
Engineering course with a global focus. Non-engineering course with a global focus. US engineering course with an international project.	Coursework	Curricular course for credit that had a global focus (engineering and non-engineering).	
Study abroad. Dual degree program with an international university.	Study Abroad	Traditional study abroad models, as well as student exchanges.	
US based research project that examines a global issue. Internship/co-op/technical research project conducted internationally.	Work or Project	Experiences that involved hands-on, authentic work in an international setting, including research projects abroad or on a global issue, and work experiences abroad (i.e., internships or co-ops).	Co-curricular
University housing with international focus. Engineering focused service learning program. Non-engineering focused service learning program.	Student Organizations	Formal student organizations (i.e., EWB), service organizations (e.g., ESW), and internationally engaged learning communities (e.g., international roommates).	

* Living abroad (e.g., military service, expatriate living, foreign born) were less than 1% of sample and were excluded for analysis.

Table 3. GPI Dimensions and Subscales [9]

Dimension	Subscale	α*	Description
Cognitive	**Knowing**	0.66	Degree of complexity of one's view of the importance of cultural context in judging what is important to know and value.
	Knowledge	0.77	Degree of understanding and awareness of various cultures and their impact on our global society and level of proficiency in more than one language.
Intrapersonal	**Identity**	0.74	Level of awareness of one's unique identity and degree of acceptance of one's ethnic, racial, and gender dimensions of one's identity.
	Affect	0.73	Level of respect for and acceptance of cultural perspectives different from one's own and degree of emotional confidence when living in complex situations, which reflects an "emotional intelligence" that is important in one's processing encounters with other cultures.
Interpersonal	**Social Responsibility**	0.73	Level of interdependence and social concern for others.
	Social Interaction	0.70	Degree of engagement with others who are different from oneself and degree of cultural sensitivity in living in pluralistic settings.

* Cronbach's alpha is an estimate of the reliability of a test's scores and score interpretation.

development and intercultural communication theory (Table 3).

Braskamp notes that "as one develops an enlarged global perspective, she incorporates more complex ways of making meaning that are grounded in intercultural knowledge, cultivates greater acceptance of cultural differences and solidifies her sense of self, and develops more mature interpersonal relationships and a stronger commitment to social responsibility" [21]. Braskamp indicates that this view of student development is holistic and integrative because students need to develop all three dimensions if they are to become mature persons [25].

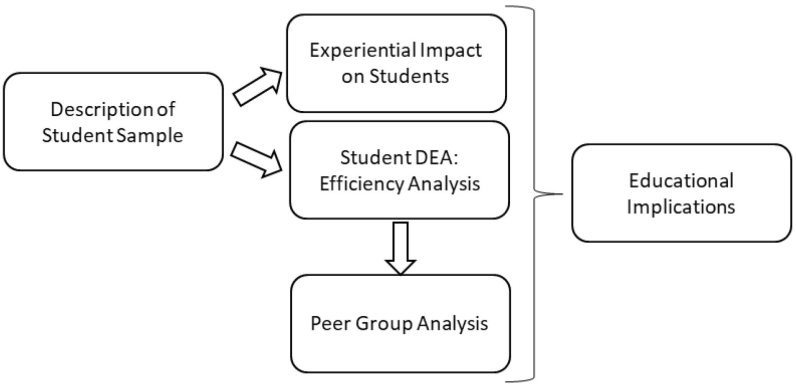

Fig. 1. Analytic Plan for Study.

3.2 Analytic strategy

Several analytic methods are used to answer the study's research questions, and are outlined in Fig. 1. Descriptive statistics for all input and output variables are calculated and displayed for the GPI dimensions and organized by subgroups (sex, ethnicity, multilingual, and parents' degrees). The total number and variety of international experiences types, as well as statistics on the educational type of each international experience is reported. Spearman correlations are calculated to get an initial understanding of the relationship between the GPI dimensions and international experience types. Ordinary least squares regressions are then conducted on the GPI dimensions (output variable). Data Envelopment Analysis (DEA) is then employed to capture student efficiency scores, including a deep dive peer group analysis into the most robustly efficient students. The international experience types that yield the largest global perspective impact are described in the context of existing international programs that fall into that experience type.

4. Methodology

4.1 Student Sample

The survey was administered to engineering students across 14 participating institutions. These institutions were selected based on their interest and activity in international engineering education, geographic location, and affiliation in an effort to be representative of those US institutions that are supportive of such activities. The NSF project this study is derived from collected survey responses from 2,853 students, including students who: had no international experiences, only had international experiences prior to college, only had international experiences during college, and had international experiences prior to and during college. However, the purpose of this study was to examine the relative impact that international experiences have on students in college so that administrators and facilitators can receive actionable information about the global programming strategies being employed. Therefore, only the subset of senior students who had experiences *during college only* was included in the present study. Students with missing data or exceedingly high frequency of international experience frequencies due to misinterpreting the question (i.e., counting total semesters, hours instead of frequency) were removed which accounted for approximately 7.9% of the sample. The final sample size consisted of 301 senior engineering students (see Table 4).

Approximately 62.1% of the students were male; and 74.4% were white, with students of color including Asian/Pacific Islander (15.0%), and underrepresented minority groups (URM) (10.6%). Nearly 20.3% of the students indicated that the highest educational attainment of their parents was a high school diploma or associates degree, and over a third of the students (39.2%) indicated they were fluent in a second language.

4.2 Data envelopment analysis

DEA was developed by Charnes, Cooper, and Rhodes in 1978 [10] as a means of efficiency evaluation in the context of 'not-for-profit entities participating in public programs'. This followed the work by Dantzig [46] and Farrell [47] decades prior. DEA is a non-statistical, non-parametric mathematical programming based approach for estimating a piece-wise linear production function that computes a comparative ratio of outputs to inputs for each DMU, which is reported as the relative efficiency score. There is an implicit assumption that there is a relationship between the outputs and inputs in the model (e.g., a relationship between international experiences and global perspectives). A DMU is any entity that produces one or more outputs from one or more inputs. Using linear

Table 4. Descriptive Statistics on Backgrounds for Participants

Sex	Count	Percentage (%)
Male	187	62.1
Female	114	37.9
Parent's Educational Background	**Count**	**Percentage (%)**
High School or Associate	61	20.3
BS	122	40.5
MS or PhD	118	39.2
Second Language Fluency	**Count**	**Percentage (%)**
No	183	60.8
Yes	118	39.2
Ethnicity	**Count**	**Percentage (%)**
White	224	74.4
Asian	45	15.0
Underrepresented Minority (URM)	32	10.6

programming methods, a production possibility or "best-practice" frontier is created for the measured population. The basic concept is that the efficiency of each DMU is evaluated against its own performance and that of each of the other DMUs in the sample. The DMUs that are most efficient form a best-practice frontier and the less efficient DMUs are described by a number that indicates their distance from that frontier [10].

Given the heterogeneity of college students, assessing the impact of education for any individual student is difficult. The presence of multiple inputs and multiple outputs make DEA an instructive tool in the education space. Because of the hierarchical structure of student data and the difficulty in obtaining such data, there have not been many applications of DEA, with researchers opting for multilevel modeling statistical approaches instead. Thanassoulis and Portela were one of the first to apply DEA to student-level data [48–50]. These papers originally attempted to set achievement targets for school children, and later investigated the source of student attainment. DEA has several advantages compared to other analysis techniques. Because it simultaneously analyzes multiple inputs and outputs, and it generates relative-efficiency information, it provides information not readily available with other techniques. DEA also does not attempt to find the "best-fit" of the data like many statistical techniques attempt to do. Rather, it determines those DMUs that have maximized the use of inputs to create an efficiency frontier. Instead of identifying average performance, it distinguishes the most efficient performance and looks explicitly for the maximal performers in the dataset.

Over the past 40 years, education has been represented as an example of a sector which has been well served by DEA. The application of DEA to universities has generally focused on the efficiencies of university programs or departments [16, 17, 51], whether that is measuring performance and fee-paying enrollments, measuring the efficiency of research output in academic departments, or the teaching effectiveness. Research on school effectiveness started in the 1960's with the controversial study "Equality of Educational Opportunity" [52]. Results from this report indicated a lack of importance of the school in explaining academic attainment. This counterintuitive finding led to a number of studies whose goal was to prove that schools and the activities therein do make a difference. These studies began to model education as a process, where student outcomes were a function of a multitude of variables, categorized into family background, peer influences, school inputs, and innate abilities of students [13, 53].

Consider the context of international education where the inputs are the number and types of experiences a student has engaged in and outputs are the global perspective measures. If the goal is to identify students that are over-utilizing international experiences, then it would appear that reducing the number of experiences while achieving the same level of global perspective is the central focus. On the other hand, if the goal is to identify students that could improve their global perspectives without participating in any more international experiences, than output enhancement, not input reduction will be the focus [54]. This study classifies students as either efficient or inefficient compared to the other students in their peer group, where the peer group is comprised of efficient students most similar to that student in their pattern of international experiences and global perspectives.

Fig. 2 shows the elements involved in the DEA of engineering students' global perspective development. There are six input variables of interest for this study, which includes the frequency of each type of international experience learning type. The three output variables analyzed are the scores on the GPI dimensions. With a sample of 301 engineering students, the number of variables in the model is well below the recommended maximum. Operational/programmatic elements of international experiences are indicated in Fig. 2, even though these were not included in the model. These elements describe the components that qualitatively describe an international program, informed by the work of Besterfield-Sacre et al. [28] and Engle and Engle [55]. These components help describe the potential reasons particular experience types are more impactful but are not studied in detail in this research.

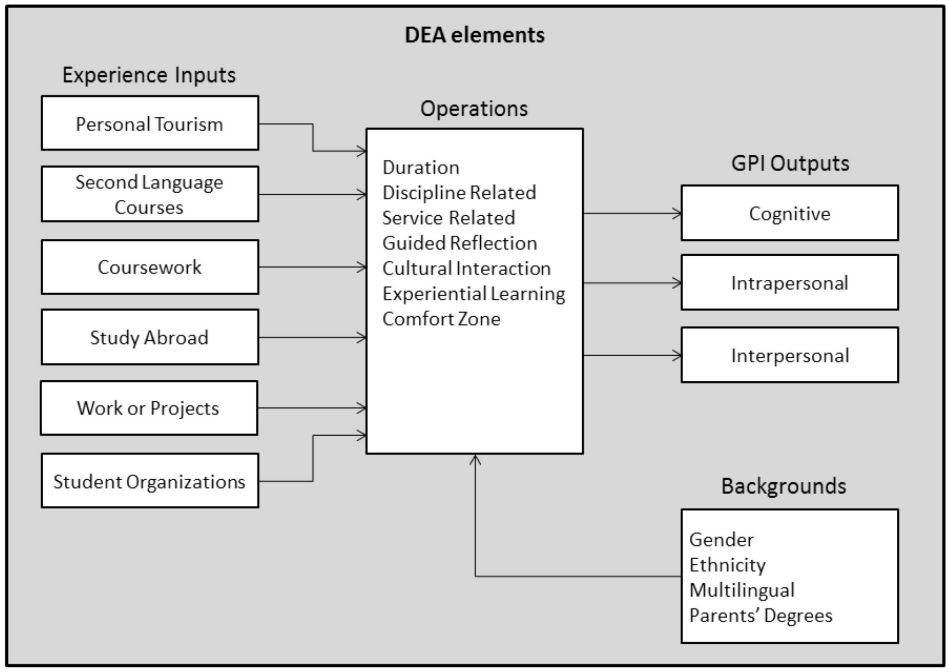

Fig. 2. DEA elements for each engineering student.

5. Results and discussion

5.1 Description of students-preliminary analysis

Inputs: Table 5 shows the frequency of international experiences in the sample of 301 undergraduate senior students who only had experiences during college. The most frequent experience was personal tourism, with almost half (43.9%) of the seniors having this type of experience in college. This is followed closely by coursework (38.5%) and study abroad (37.2%). Work and project experiences are the least frequent (15.9%). Looking closer, assuming a student has had a particular experience type, second language courses (regardless of fluency) and student organizations are the most frequent; and study abroad and work/project experiences are the least frequent. Curricular international experiences were the most common, with almost two-thirds of the sample participating in this type of experience. Co-curricular experiences were the least common, with less than one-third of the sample participating in this type of experience.

Work by Kilgo, Sheets, and Pascarella has suggested that educational practices such as undergraduate research and study abroad are positive predictors for intercultural effectiveness [39] and prior work by Salisbury, An, and Pascarella found that on-campus diverse interactions and integrative learning also influenced intercultural competence development [24]. Initial findings in this study indicate that most engineering students are not participating in these high-impact practices in large numbers, as our sample also seems to indicate (15.9%). This is primarily due to participation barriers for these types of experiences, especially in regards to the highly sequenced engineering curri-

Table 5. Inputs—Frequency of International Experiences

Experience Type	No. of Students	Average	Average (>0)*	Percent of Total
Personal Tourism	132	0.85	1.88	43.9%
Second Language	51	0.40	2.35	16.9%
Coursework	116	0.56	1.47	38.5%
Study Abroad	112	0.42	1.14	37.2%
Work or Projects	48	0.22	1.35	15.9%
Student Organizations	95	0.78	2.46	31.6%
Educational Type	**No. of Students**	**Average**	**Average (>0)**	**Percent of Total**
Curricular	199	1.39	2.10	66.1%
Co-curricular	94	0.70	2.23	31.2%
Extracurricular	174	1.15	1.99	57.8%

* Average (>0) represents the average number of experiences given a student has had at least 1 of that type.

Table 6. Distribution of Variety of Experience Types

Variety of Experiences	Count	Percentage (%)
1	152	50.5%
2	82	27.2%
3	39	13.0%
4	15	5.0%
5	12	3.99%
6	1	0.33%

culum [38]. Over half of the sample of college seniors have one type of international experience in college (Table 6). It is worth noting that out of the 152 students with one type of experience, 102 students still only had one experience total while 50 had more than one experience of the same type. Together, this implies that the majority of engineering students in this sample are not taking advantage or given the opportunity to participate in high-impact practices related to their global perspectives, nor are they experiencing the breadth of international opportunities available to them.

Spearman correlations were calculated to examine the relationship between the various input measures in the study and the GPI dimension scores. Tables 7 breaks down the correlations between experience types, educational types, total and variety of international experiences. The number of work/projects an engineering student has participated in has positive correlations across all GPI dimensions, and the number of study abroad experiences is positively correlated with the Cognitive dimension. This initially suggests that these types of experiences (international work/projects and study abroad) have the greatest impact on global perspectives, especially in the Cognitive dimension. Moreover, the number of curricular and co-curricular international experiences is positively correlated with the Cognitive dimension. The total number of experiences and number of different types of experiences is positively correlated with the Cognitive dimension. The number of different types of experiences has a higher correlation with the Cognitive dimension than the raw number of experiences. This indicates that the greatest gains in global perspectives may occur when students have multiple, diverse exposures to different international experiences, which helps students recognize the importance of cultural context in judging what is important to know and understand various cultures and their impact on society.

Fig. 3 depicts the average scores in the Cognitive dimension for a unit increase in both the total number of experiences and variety. Data on senior engineering students with no international experiences is included in this table and is from the larger dataset for which this study is based. It initially appears that the variety of international experiences is more indicative of higher GPI scores in the Cognitive dimension.

Outputs: The GPI dimension scores were calculated for each subgroup in the study (see Table 8). Female engineering students scored significantly higher than males in the Cognitive and Interpersonal dimensions. Underrepresented minority students and Asian students scored significantly higher than white students in the Interpersonal dimension. Finally, engineering students who are multilingual scored significantly higher than students who are not multilingual in the interpersonal dimension. No significant differences in global perspectives exist between first generation college students and those students who have at least one parent with an advanced degree. It initially appears that the difference in global perspectives between subgroups is fairly minimal for those students with international experiences *in college only*. Significant differences exist mostly in the Interpersonal dimen-

Table 7. Spearman Correlations

Experience Type	Cognitive	Intrapersonal	Interpersonal
Personal Tourism	0.063	0.027	–0.017
Second Language	0.073	0.014	0.091
Coursework	0.068	–0.019	0.046
Study Abroad	**0.177***	0.044	0.083
Work or Projects	**0.175***	**0.152***	**0.122***
Student Organizations	0.051	0.062	0.039
Educational Type	**Cognitive**	**Intrapersonal**	**Interpersonal**
Curricular	**0.137***	–0.030	0.061
Co-Curricular	**0.138***	0.065	0.094
Extracurricular	0.081	0.071	–0.026
Breadth	**Cognitive**	**Intrapersonal**	**Interpersonal**
Total	**0.156***	0.030	0.059
Variety	**0.241***	0.097	0.101

*Significant at $p < 0.01$.

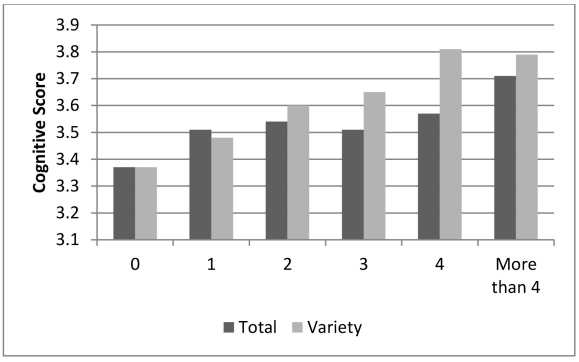

Fig. 3. Comparison of Cognitive Scores by Total and Variety.

sion, which describes how students relate to others from different cultures, backgrounds, and who have different values.

5.2 Experiential impact on students global perspectives

The Spearman correlations in Table 7 indicate that the strongest relationship between the number of international experience types and GPI scores occurs in the Cognitive dimension. Therefore, when analyzing the experiential impact on student global perspectives, the primary output of interest is the Cognitive score. Ordinary least squares regressions were conducted on this dimension, using the various input measures as predictors. Three models were formulated, one for each set of experience input measures. Table 9 describes the results of the least squares regression analyses. A stepwise regression analysis was conducted on the model using frequency of experience types as a predictor to find the parsimonious combination of international experiences that yields the highest Cognitive scores. The other two regression analyses using educational types and breadth were conducted on all predictors due to the smaller number of variables. The low R^2 values in Table 9 are noteworthy but not unexpected. The purpose of the modeling is to identify potential relationships between experience types and GPI scores and is not predictive in nature.

Table 8. Outputs—GPI Dimension Averages by Subgroup

	n	**Cognitive**	**Intrapersonal**	**Interpersonal**
Total	301	3.57	3.97	3.40
Sex	**n**	**Cognitive**	**Intrapersonal**	**Interpersonal**
Males	187	3.53[a]	3.98	3.36[a]
Females	114	3.62[b]	3.96	3.46[b]
Ethnicity	**n**	**Cognitive**	**Intrapersonal**	**Interpersonal**
White	224	3.58	4.00	3.34[a]
Asian	45	3.52	3.83	3.54[b]
URM	32	3.51	3.99	3.55[b]
Multilingual	**n**	**Cognitive**	**Intrapersonal**	**Interpersonal**
No	183	3.55	3.94	3.34[a]
Yes	118	3.59	4.02	3.49[b]
Parents' Degree	**n**	**Cognitive**	**Intrapersonal**	**Interpersonal**
HS or Associate	61	3.55	3.95	3.45
BS	122	3.56	3.97	3.35
MS or PhD	118	3.58	4.00	3.42

* Different subscripts in a column represents statistically different means ($p < 0.05$).

Table 9. Least Squares Regression Results (Inputs with GPI Cognitive Dimension Scores)

	Experience Types $R^2 = 0.06$				**Educational Types $R^2 = 0.03$**				**Breadth $R^2 = 0.06$**		
	β	**S.E.**	**p-value**		β	**S.E.**	**p-value**		β	**S.E.**	**p-value**
Work/Project*	0.13	0.04	0.002	**Curricular**	0.04	0.01	0.01	**Total**	–0.00	0.01	0.82
Study Abroad	0.11	0.04	0.005	**Co-curricular**	0.00	0.01	0.80	**Variety**	0.09	0.03	0.00
				Extracurricular	0.02	0.02	0.14				
Constant	3.49	0.03	0.00	**Constant**	3.49	0.04	0.00				
Constant	3.39	0.04	0.00								

* Only significant predictor of Intrapersonal and Interpersonal scores.

The findings from the regression analyses shows that work/projects and study abroad have a significant relationship ($p < 0.01$) on the Cognitive dimension of the GPI (and the number of work/project experiences was also significant on the intrapersonal and interpersonal scores). Curricular experiences have a significant, but marginal, effect on the cognitive score. Finally, when accounting for the number of international experiences an engineering student has participated in, variety of experience types showed a significant and positive relationship ($p < 0.01$) with Cognitive scores. Likewise, when controlling for the variety of experience types, the total number of experiences is not significant. This suggests that international/work projects and study abroad experiences in college is mostly related to epistemological processes used to evaluate and make meaning of different knowledge sources and acquiring knowledge to enlarge the understanding of cultural differences [56].

This also supports the finding that students benefit more in terms of their global perspectives when engaged in *different* international experiences (in contrast to simply having a multitude of them). So while international internships, co-ops, and research projects, along with study abroad, appear to be the most impactful on students' global perspectives, the results stress the importance of engineering schools having a variety of program types in their portfolio. Not all experiences target the same learning outcomes and having a multitude of different types of experiences may allow students to conceptualize what they have previously learned in context and consequently transfer that knowledge to new situations. While the depth of an international experience has been documented [55, 57, 58], the importance of breadth of international experience engagement has been understated in the literature. Furthermore, there seems to be a misalignment between the types of international experiences that have the most impact, and the actual experiences most students engage in as described above. Hence, engineering programs may wish to prioritize strategies that make study abroad programs and international internships/co-ops/research project more accessible to their respective student populations.

It is recognized that the resources and time required for faculty and students alike to be engaged in global programming, let alone a variety of different experiences, is a constraint on the system that cannot be ignored. This underscores the importance of determining which types of international experiences have the most impact on engineering students, so that resources and time can be allocated efficiently. DEA is used to explore this impact and the factors that affect efficiency.

5.3 Student DEA: efficiency analysis

DEA was used to assist in identifying best practice performance in relation to engineering student global perspectives. Data collected on international experiences (inputs) and dimension scores on the GPI (outputs) formed the basis of the analysis. Using non-parametric linear programming methods, DEA was used to compute an international experience "best practice" or efficiency frontier, as well as the relative inefficiencies of those students not on this frontier. Mathematically, a student on the frontier will have an efficiency rating of 1 and students not on the frontier will have a rating less than 1, but nonnegative (Fig. 4).

Student efficiency in this type of model is broken down into two components: *technical efficiency* and *scale efficiency*. In the context of global perspectives, technical efficiency is a measure by which students are evaluated for their global perspectives relative to the performance of other students in the peer group. Scale efficiency is the extent to which a student can take advantage of returns to scale by changing the number of international experiences toward the optimal amount, defined as the region in which there are constant returns to scale in the relationship between global perspectives and international experiences [59]. Technical and scale efficiency are defined as follows [11]:

$$e_j = \frac{\text{weighted output}}{\text{weighted input}} = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \text{for } j = 1, \ldots, n,$$

Where e_j is the technical efficiency score given to student j; x and y represent inputs and outputs and v and u denote input and output weights, respectively; s is the number of inputs ($s = 1, 2, \ldots m$), r is the number of outputs ($r = 1, 2, \ldots, n$). Consequently, scale efficiency (SE) is calculated in the following way for each student:

$$SE = \frac{\theta^*_{PTE}}{\theta^*_{OTE}}$$

where θ^*_{PTE} is the optimal efficiency rating for a student under a constant returns to scale model and θ^*_{OTE} is the optimal efficiency rating for a student

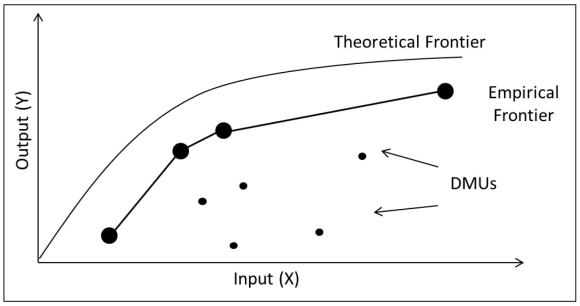

Fig. 4. Theoretical and Empirical Efficiency Frontier.

under a variable returns to scale model. The benchmarking software chosen to implement the selected models was OSDEA—i.e., Open Source Data Envelopment Analysis [60].

Technical and scale efficiency scores are calculated for each student and students deemed technically efficient are contrasted against those deemed inefficient. It is worth noting that efficiency measures address the question: "By how much can the number of experiences be proportionally reduced without altering the global perspective scores?" Table 10 presents the overall technical efficiency scores (OTE), pure technical efficiency (PTE) scores and scale efficiency (SE) scores.

OTE combines the efficiency that is due to pure technical (or operational) efficiency and efficiency that is due scale efficiency (i.e., appropriate number of experiences). PTE scores assume that all inefficiencies directly result from student inefficiency in not getting the most out of their past international experiences or, more likely, not choosing the most beneficial experiences. The scale efficiency (SE) is the ratio of efficiency with a constant return to scale (OTE) with the efficiency with a variable return to scale (PTE). The average OTE score was 0.502, which suggests that an average student, if producing on the global perspective best practice frontier instead of his/her current location, could participate in 50% fewer international experiences. This suggests that by adopting programmatic best practices, students on average can reduce the number of experiences they participate in by almost half and still maintain the same global perspective level. However, the potential to reduce the amount of experiences from adopting best practices varies from student to student. Alternatively, students also have the scope of scoring two times (i.e., 1/0.50) higher on the GPI from the same number of international experiences.

Thirty-six (36) students were found to be "locally efficient" since they had a PTE score of 1 (Table 11). These students together define the best practice frontier under the variable returns to scale assumption and form the peer group for inefficient students (see efficient frontier illustration in Fig. 4). Seventeen (17) of these students were found to be "globally efficient" since they also had OTE scores of 1. This second group of students defined the best practice frontier under the CRS assumption. So inefficiency in global perspective development seems to be due to both poor experience utilization (i.e., not getting as much out of an experience as other students) and failure to operate at the most productive scale size (i.e., not participating in enough different experiences), with the majority of students falling into the former category. The average PTE score has been observed to be 0.556. This implies that 44.4 percentage points of the 49.8 percent of OTE is due to students who are not following best practice and participating in a less than optimal experiences in regards to global perspective development. The rest of the OTE is due to students simply going on too many similar experiences that do not lead to an increase in their global perspectives in return. Based on this result, it is posited that the underlying problem is not that students are not going on enough international experiences while in college. In fact, the Institute of International Education (IIE) latest Open Doors report suggests that U.S. engineering students are participating in more international experiences than ever before and the rate of increase is substantial [7]. It appears instead that students are under utilizing the experiences they are currently going on by not participating in ones that provide the largest impact. This could be due to the structure and quality of the experience itself [55, 57], the innate qualities of the student [61], or simply engaging in low impact experiences.

To fully describe the 36 efficient students, a benchmarking method used by Kumar and Gulati [62] was adopted. This uses the frequency of the peer groups to distinguish between them. The frequency with which an efficient student shows up in the peer groups of inefficient students represents the extent of robustness of that student relative to other efficient students. A student that appears frequently in the peer groups of inefficient student is likely to be a student who is efficient with respect to a large number of factors, and can be considered a "well-

Table 10. Descriptive statistics of efficiency scores (technical and scale)

Statistics	OTE	PTE	SE
N	301	301	301
Average	0.502	0.556	0.937
SD	0.32	0.33	0.19
Average inefficiency (%)	49.8%	44.4%	6.3%

Table 11. Experience Averages of Efficient and Non-Efficient Students

Student Groupings	Efficient	Not Efficient
n	36	265
Inputs		
Personal Tourism	0.83	0.86
Second Language	0.33	0.41
Coursework	0.36	0.59
Study Abroad	0.33	0.43
Work or Projects	0.42	0.19
Student Organizations	0.47	0.82
Outputs		
Cognitive	3.98	3.51
Intrapersonal	4.48	3.91
Interpersonal	4.03	3.31

Table 12. Breakdown of Efficient Students (N = 36)

	Personal Tourism	Second Language Course	Coursework	Study Abroad	Work/ Project	Student Organizations
n*	16	7	12	10	10	11
Efficiency Average	0.83	0.33	0.36	0.33	0.42	0.47
Efficiency Average (>0)	1.88	1.71	1.08	1.2	1.5	1.55
Total Average	0.85	0.40	0.55	0.42	0.22	0.78
Total Average (>0)	1.88	2.35	1.47	1.13	1.35	2.46
Difference in Average	–0.02	–0.07	–0.20	–0.09	**0.20**	–0.31
Difference in Average (>0)	–0.00	–0.64	–0.38	**0.07**	**0.15**	–0.92

* Number of students who have participated in that type of experience.

rounded performer.'' Efficient students who rarely appear in the peer groups are likely to possess very uncommon experiences/global perspectives mix and are not suitable examples for other students to emulate. Students with zero frequency in the peer groups are termed ''efficient by default'' because they do not possess characteristics which must be followed by other inefficient students. Table 12 provides the summary of efficient students.

Students who were categorized as efficient have, on average, less experiences of every type except for work/project experiences. Personal tourism only had a very slight change in differences in averages. Consequently, second language courses, coursework, and student organizations are not associated with efficient students, which suggest their impact on global perspectives may be more limited when done in isolation compared to higher impact experiences such as study abroad and work/project experiences. Personal tourism does not appear to have much of an effect on efficiency one way or the other. Out of the 36 efficient students, 4 were categorized as *well-rounded performers* and 11 were categorized as *efficient by default*. The *well-rounded performers* all have only 1 experience, each with a different experience and slightly different background. The experiences included in this subset include personal tourism, coursework, study abroad, and student organizations. The well rounder performers are the benchmark for which inefficient students should try to meet, since participating in one international experience in college is more easily attainable than multiple. The most robust student (i.e., the student who was included in 34% of the peer groups, the highest of any student) was a white, male student with a study abroad experience in college. This experience was 1–3 months in duration, was not engineering related, nor had any journaling or service components. The 11 *efficient by default* students had more experiences, on average, than the rest of the efficient students in the sample especially personal tourism, work/project experiences, and student organizations. These students were not included in any of the peer groups, and were not used as a reference for efficiency. The experience patterns these students exhibited is difficult to replicate by others and there are other students in the efficiency group that had more representative experiences.

6. Educational implications

The primary objective of this study was to explore what factors are related to global perspective development and investigate how engineering students can make the best use of international experiences while in college (by identifying which experience types are most effective). Statistical analyses (correlations and least squares regression), DEA, and a resulting benchmarking analysis were applied to examine the relative impact that background characteristics and types of international experience participation in college have on engineering students' global perspectives.

This study found that for students who come to college with no prior international experiences, background characteristics mainly affect the interpersonal dimension, which consists of interdependence, social concern for others, engaging with others who are different, and being culturally sensitive. Females, underrepresented minority students, and those who are fluent in another language scored significantly higher in this dimension. For females, the GPI manual [9] suggest the increase in the interpersonal dimension compared to males is due to social responsibility. No significant differences were found for first generation college students. It is worth noting that only one of the GPI dimensions (interpersonal) was significantly related to engineering student backgrounds. This initially indicates the difference in impact that international experiences between student groups is minor, at least for those students who all have similar upbringings (i.e., no prior international experiences). Future research is needed to further explore this phenomenon, including how students' precollege experiences affect their global perspective development while in college. Given the increasing diverse student population

Table 13. Engineering International Internship and Research Projects included in Study

Program Name	Source
Global Internship Program (GIP)	oie.gatech.edu/gip
Global Internships and Education Abroad	egr.msu.edu/global/map/international-presence
Researching Fresh Solutions to the Energy/ Water/Food Challenge in Resource Constrained Environments (REFRESCH)	thirdcentury.umich.edu/refresch/
International Internship Program	seas.virginia.edu/admin/pdf/international_internship.pdf
Interactive Qualifying Project (IQP)	wpi.edu/academics/undergraduate/project-based-learning/interactive-qualifying-project

entering the engineering discipline, global programming strategies should make concerted efforts to attract a diverse set of students to participate in international experiences and design programming portfolios around the multitude of student needs and interests.

The preliminary findings also indicate that engineering students are not engaging in the types of international experiences that provide the largest impact on global perspectives as measured by the GPI. More specifically, the least frequent experience type of internships, co-ops, or technical research projects conducted abroad also had the highest association with the GPI dimensions, and DEA revealed that these types of experiences are also associated with global perspective development efficiency. This is not surprising given the logistic hurdles of sending engineering students abroad, which includes a content-full, highly sequenced curriculum, risk in delaying graduation, and finding suitable partners abroad [38]. The DEA findings also indicated that the inefficiencies in global perspective development could be due to students not getting as much out of the opportunity as their peers, caused either by what the student is bringing to the experience or the structure/quality of the experience itself. Inefficiencies were only marginally caused by students engaging in a large number of experiences without the expected global perspective return. The educational strategy around this finding should be to encourage students who have not had any international experiences to participate in one, since the largest impact on global perspectives happens when a student goes on their first international experience/program (Fig. 3). But more importantly, design global programming strategies around a variety of high-impact practices and encourage students to engage in these types of experiences, specifically international work or research opportunities. Students who want to maximize their global perspective development in college should therefore (1) seek out high-impact global programming programs and/or (2) participate in varied experience types that are curricular and co-curricular in nature. This analysis and the assumptions therein support a means by which global perspectives *should* be developed in students that is often understated in strategic internationalization plans and global programming strategies. Instead of designing programming with the goal of turning the entire student population into high scoring students, engineering schools should instead attempt to improve the global perspectives of students to what is empirically possible given the experiences available to them, mediated by their upbringing and background.

As mentioned previously, internships, co-ops, and research projects conducted internationally emerged as the most impactful type of experience both in terms of associations with the scores of the GPI dimension and "dosage" required for meaningful global perspective gains. While the connection between impact and particular international programs was not explored, an overview of the programs that fit into this experience type from the sample are described and can be viewed as "exemplary programs" of high-impact practice in international engineering education (Table 13).

7. Conclusions

International experiences are viewed as important components of undergraduate engineering education; yet, a relatively small number of students participate in these types of experiences because it's perceived as expensive, a delay to graduation, or less important than other experiences such as domestic internships. This research study was conducted to explore how engineering students utilize international opportunities in college and determine which types of programs have the most impact on a student's global perspectives. Statistical analyses and Data Envelopment Analysis were used to explore the types of international experiences senior engineering students participated in, the relative efficiency of student experience patterns, the reasons for inefficiency in international experience engagement, and the differences in global perspective development among subgroups. Results from this study suggest that internships, co-ops, and technical research conducted abroad provide the largest impact to improving global perspectives

while also being the least frequent type of experience. Further, the largest gains in global perspectives occurs after one international experience or by participating in a variety of experience types. This study provides initial empirical evidence on the differential impact of international experiences for engineering students, giving global engineering program facilitators a better understanding of where to focus their programming efforts and how to advise students to best take advantage of the international opportunities while in college. To prepare future engineering student populations to be globally competent, an understanding of the most impactful strategies and programs, given a relative crowded engineering curriculum, is critical. As engineering schools and institutions continue to invest time and resources into education abroad experiences, it is important to determine how students can get the most impact from the fewest number of experiences, especially as students are presented with more and more options as to the types of activities and educational practices they can engage in during college.

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