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Measuring the Educational Benefits of Diversity in Engineering Education: A Multi-Institutional Survey Analysis of Women and Underrepresented Minorities

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interests consider two areas within higher education: (a) identity intersections with specific consideration of race, gender, sexuality and spirituality as social identities and (b) organizational socialization of administrators in higher education.

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Abstract

Changing demographics of the U.S. population drive growing emphases on diversity in engineering education. Still, questions persist about the educational benefits of race and gender diversity within the student population, despite decades of supportive research. The present study sought to estimate the educational benefits that accrue to undergraduate engineering students who interact with diverse peers and perspectives. Furthermore, differences across gender and race were explored. Multi-institutional survey data were analyzed for over 100 undergraduate engineering students using a 2007 administration of the National Survey of Student Engagement (NSSE). Findings show that encouraging contact among students from different economic, social, or racial/ethnic backgrounds can produce greater perceived learning gains amongst engineering students.

Introduction

In recent reports, based in part on the Supreme Court's rulings in affirmative action cases at the University of Michigan, several national organizations (e.g., National Academy of Sciences, National Academy of Engineering, and National Action Council for Minorities in Engineering) argue that the importance of diversity is heightened in the fields of science and engineering.[1] To illustrate the need for increased diversity, consider national statistics on science and engineering workforce participation. Although White men were only 33% of the US population in 2008, they comprised some 55% of scientists and engineers. Only 18% of the workforce were White women and 7-10% were underrepresented minorities [(URMs), i.e., African Americans, Latinos, American Indians/Alaskan Natives].[2] Gender and racial representation can be even lower in specific engineering fields such as computer science/engineering, nuclear engineering, and electrical engineering, to name a few.

Several steps must be taken to improve the representation of women and racial/ethnic minorities in undergraduate engineering programs (UEPs). An important step is clearly demonstrating the educational benefits of diversity in engineering education, both for students and society.[3] While previous research provides evidence of the educational benefits of diversity in collegiate settings[4] and suggests that racially diverse educational environments produce positive academic and social outcomes for college students,[5,6] relatively few studies assess whether engagement with diverse peers and perspectives enriches UEP student experiences. This is the gap addressed by the present study.

Purpose

The purpose of the study was to estimate the educational benefits that accrue to undergraduate engineering students who interact with diverse peers and perspectives. Specifically, in this study, we conducted multivariate analyses on multi-institutional survey data from 115 engineering students at 4-year institutions to answer the following research questions: (a) What are the mean perceived learning gains of undergraduate students in engineering? (b) Are there differences in mean perceived learning gains of undergraduate engineering students by race/ethnicity or gender? (c) What is the relationship between diverse perspectives and undergraduate engineering students' perceived learning gains, controlling for confounding factors?

Literature Review

Diversity is a complex phenomenon. Previous researchers have identified three aspects of diversity to facilitate understanding of the topic: (a) structural, (b) interactional, and (c) classroom. Structural diversity refers to the demographic representation of students from different backgrounds (e.g., 6% of students at University A are Black). Interactional diversity, on the other hand, typically refers to the frequency and quality of interactions with diverse peers across numerous campus domains including, but not limited to, campus events and residence halls. Classroom diversity refers specifically to learning about diverse peers that occurs in formal instructional settings like classrooms, lecture halls, and laboratories. Maximizing achievement of the educational benefits of diversity requires all forms of diversity and educationally purposeful engagement. It is not enough for students with different social identities to simply exist at the same institutions; they must also be meaningfully engaged with one another in both curricular and co-curricular activities.[7,8,9]

Racial/ethnic diversity is associated with a broad array of positive academic and social outcomes. For example, in a study of 594 Black college students, Strayhorn found that interactional diversity experiences were a positive, strong and consistent predictor of perceived student learning outcomes.[7] In another study, Gurin, Ngada and Lopez found that students who participated in an intergroup relations program reaped a number of benefits related to civic engagement and democratic participation.[8] Students who participated in the program demonstrated an increased interest in politics, reported learning more about the contributions of other groups to society, and evaluated conflict in more productive ways than their non-participant peers. Each of these studies supports the contention that college is a critical time to positively shape the attitudes and opinions of students around difference. One way to do so is by exposing students to diverse faculty and peers. This is especially important in high need fields like undergraduate engineering where women and minorities are traditionally underrepresented. Before presenting the study, we describe the theory that undergirds our work.

Theoretical Framework

Given that the educational benefits of diversity depend on interpersonal engagement as well as the time and energy that students devote to college activities, we found Astin's theory of student involvement a useful heuristic for grounding our work. Astin proposed one of the very first college impact models, the input-environment-outcome (I-E-O) model of change. According to the model, student outcomes (e.g., perceived learning gains) are functions of two factors including inputs (e.g., demographic traits, time, energy) and environment (e.g., experiences in college).[10, 11] College impact models concentrate on the origins of change while models based on developmental theory attempt to explain the stages through which change occurs.

Astin developed this model as a guiding framework for assessment in higher education.[10, 11] His model helps better understand connections between practice and outcomes by controlling for inputs such as background characteristics of students. Inputs relate to the individual or personal characteristics that a student brings to an educational setting. One of the benefits of the model is its focus on environments that might include educational experiences, instructional practices, extracurricular programs, or interventions, like those that comprise most UEPs. Outputs generally refer to the skills or abilities that college educators desire for students. Using this framework, the present study seeks to explore the effect of interactions with diverse peers on engineering students' perceived educational outcomes while controlling for other possibly confounding factors.

Method

This study is part of a larger, longitudinal study entitled, *Investigating the Critical Junctures: Strategies that Broaden Minority Participation in STEM Fields* funded by the National Science Foundation (NSF). While the larger study consists of both quantitative and qualitative components, this report is solely based on multivariate analysis of the quantitative survey data.

Data Source. Data were drawn from a 2007 administration of the *National Survey of Student Engagement* (NSSE). The NSSE is a survey instrument designed to measure the quality and quantity of students' engagement in educationally purposeful college activities.[12,13] Items relate to participation in various curricular/co-curricular programs and activities. In addition, a set of questions designed to elicit information about student perceptions of the overall educational environment are included. NSSE is generally sent to random samples of first-year and senior students at participating institutions. To date, more than 600 colleges and universities have participated in the national survey.[12,13]

Sample. The sample for this study was restricted to only include students who were engineering majors. Thus, the analytic sample consisted of 115 respondents. Of these, the majority (70.4%) were male. White students comprised 88% of the sample, while 5.2% were Black, 4.3% were Asian/Pacific Islander, and 1.7% identified as Hispanic. The majority of the students in the sample were seniors (61.7%) and between the ages of 20 and 23 (40%). Most of the students in the sample had average grades of "B" or better (81.7%). Due to the small number of URMs in the analytic sample, race was also analyzed using a dichotomous indicator (i.e., "White" vs. "Non-White" students). Table 1 presents descriptive statistics for the sample.

Table 1: Description of sample (N=115).

Variables	%
Academic	
College classification	
Freshman, first-year	38.3
Senior	61.7
Enrollment status	
Full-time	93.0
Part-time	7.0
Grades at this college	
A	17.4
A-, B+	30.4
B	33.9
B-, C+	13.9
C, C-, or lower	4.4
Demographic	
Sex of student	
Male	70.4
Female	29.6
Race/Ethnicity	
African American/Black	5.2
Asian/Pacific Islander	4.3
Caucasian/White	88.7
Hispanic	1.7
Age of student	
19 or younger	34.8
20-23	40.0
24-29	15.7
30-39	7.0
Missing	2.6

Measures. The dependent variables—broadly categorized as learning gains—are based on the students' perceived gains in learning various skills. For example, students were asked, "To what extent has your experience at this institution contributed to your knowledge, skills, and personal development in thinking critically?" Specifically, we examined 13 items related to thinking critically, working with others, and using technology, to name a few. Each item was placed on a 4-point Likert-type scale ranging from 1 (*very little*) to 4 (*very much*). In this analysis, we computed several psychometrically-reliable composite scales (e.g., "practical competence" and "personal/social growth") by averaging all items that loaded on the factorially-derived scale; thus, mean composite scores also ranged from 1 to 4, where higher scores represented higher perceived learning gains. This analysis yielded three scales: (a) practical competency, (b) general education, and (c) personal and social development. Cronbach's alphas for each scale are presented here: practical competency (5 items, α =0.77), general education (4 items, α =0.79), personal and social development (6 items, α =0.81) scales.

The independent variables—broadly categorized as diverse perspectives—assessed how often students interacted with diverse peers and perspectives. For example, a sample item asked: "In your experience at your institution during the current school year, about how often have you had serious conversations with students of a different race or ethnicity than your own?" Specifically, we used 6 items from the survey that tapped students' encounters with diverse people and perspectives in college. One of the 6 items (i.e., "Relationships with other students") was placed on a 7-point scale ranging from 1 (*unfriendly, unsupportive, sense of alienation*) to 7 (*helpful, considerate, flexible*). The remaining five items were placed on a 4-point scale ranging from 1 (*very little*) to 4 (*very much*). Table 2 presents means and standard deviations for all of the independent and dependent variables in the analysis.

Table 2: Descriptive statistics for diverse perspectives and learning gains

	M	SD
Diverse perspectives		
Diverse perspectives in class discussions or writing assignments	2.36	0.98
Serious conversations with students of a different race or ethnicity	2.72	0.92
Serious conversations with students who have different religious beliefs, political opinions, or personal values	2.87	0.92
Better understand someone else's views by imagining issue from his or her perspective	2.71	0.91
Relationships with other students	5.67	1.21
Encouraging contact among students from different economic, social, and racial or ethnic backgrounds	2.21	1.00
Learning Gains		
Acquiring a broad general education	3.05	0.78
Acquiring job or work-related knowledge and skills	2.82	0.99
Writing clearly and effectively	2.73	0.95
Speaking clearly and effectively	2.53	0.98
Thinking critically and analytically	3.37	0.77
Analyzing quantitative problems	3.43	0.81
Using computing and information technology	3.42	0.80
Working effectively with others	3.07	0.91
Learning effectively on your own	2.99	0.87
Understanding yourself	2.56	0.97
Understanding people of other racial and ethnic backgrounds	2.22	0.88
Solving complex real-world problems	2.81	0.94
Developing a personal code of values and ethics	2.45	1.05

To enhance the rigor of the analysis, we included statistical controls for potentially confounding variables based on our collective understanding of diversity, college student learning, and the study's theoretical framework. Several factors were controlled for in the study including gender, race/ethnicity, age, class level, enrollment status, and grades.

Data analysis. Data analysis proceeded in four stages. First, descriptive statistics were calculated to describe the sample and to determine any existing patterns among data points. Second, correlation analyses were conducted to estimate the magnitude and direction of the statistical relationships among the independent and dependent variables used in this analysis. Third, *t*-tests and chi-square (X^2) tests, were used to measure statistical significance of differences in means and frequencies across groups. Fourth, hierarchical regression analysis was employed to measure the "net effect" of engagement with diverse peers and perspectives on engineering students' perceived learning gains in three areas: personal and social development, general education, and practical competence.

It is important to note that less than 3% of the variance in the dependent variable was attributed to institution-level differences, thus multi-level modeling techniques (e.g., HLM) were deemed unnecessary.[14] Hierarchical linear regression (HLR) was the analytic technique of choice, as it is designed to test the statistical relationships between variables, controlling for variables identified by the research in advance. Variable relations were hypothesized in consonance with the study's overarching theoretical model. In this study, we employed Astin's I-E-O model to measure the influence of interactions with diverse peers and perspectives on engineering student learning outcomes.

Results

Descriptive statistics indicate that undergraduate engineering students report perceived learning gains in terms of analyzing quantitative problems ($M = 3.43$, $SD = 0.81$), using technology ($M = 3.42$, $SD = 0.80$), thinking critically ($M = 3.37$, $SD = 0.77$), working with others ($M = 3.07$, $SD = 0.91$), and acquiring a general education ($M = 3.05$, $SD = 0.78$). However, participants' responses to issues relating to diverse perspectives and interactions yielded lower scores. For example, encountering "diverse perspectives in class discussions or writing assignments" averaged 2.36 ($SD = 0.98$).

Results from tests of group differences varied. For instance, there were no statistically significant differences between the group means of men and women and their reported learning gains. The only learning gain that showed statistically significant differences by race was general learning gains ($F_{3, 111} = 2.84$, $p < 0.05$),with Whites scoring ($M = 64.46$, $SD = 21.24$) compared to non-White students ($M = 60.90$, $SD = 31.07$). Correlation results yielded only one significant, although weak, relationship; age has a negative, weak relationship with gains in personal and social development ($r = -0.22$, $p < 0.05$), including that older students in engineering tend to report lower perceived learning in this domain, compared to younger engineering peers.

Analysis of composite learning gains, race, gender, and student characteristics yielded statistically significant results. In each full model, the composite learning gains are statistically significant at $p < 0.05$. In other words, encouraging contact among students from different economic, social, or racial/ethnic backgrounds can produce greater perceived learning gains amongst engineering students. Race (i.e., White and Non-White) and gender both proved statistically insignificant predictors of positive student gains in this analysis.

Personal and social development. Hierarchical linear regression results suggest that the combination of factors had a statistically significant relationship with students' personal and social development ($F_{\text{model 2 }(12, 94)} = 2.93$, $p < 0.01$). In this model, the regression coefficient was 0.52 indicating that approximately 27% (adjusted $R^2 = 0.18$) of the variance in engineering students' perceived personal and social development in college could be explained by variables in the model. One significant predictor of engineering students' perceived personal and social development is contact with students from different economic, social, and racial or ethnic backgrounds ($B = 0.43$, $p < 0.01$). Therefore, engineering students who felt that their institution encouraged frequent and meaningful contact with peers from different economic, social, and racial or ethnic backgrounds tended to report higher scores on personal and social development than students who did not feel that way.

General education. Hierarchical regression results suggest that the linear combination of factors had a statistically significant relationship with general education ($F_{\text{model 2 }(12, 95)} = 2.09$, $p < 0.05$). In this model, the regression coefficient was 0.46 indicating that approximately 21% (adjusted $R^2 = 0.11$) of the variance in engineering students' perceived general education gains in college could be explained by variables in the model. Again, the only significant predictor of engineering students' perceived general education was encouraging contact among students from different economic, social, and racial or ethnic backgrounds ($B = 0.33$, $p < 0.01$).

Practical competence. Results from the final hierarchical regression analysis suggest that the linear combination of factors also had a statistically significant relationship with practical competence ($F_{\text{model 2 }(12, 95)} = 3.69$, $p < 0.01$). In this model, the regression coefficient was 0.56 indicating that approximately 32% (adjusted $R^2 = 0.23$) of the variance in engineering students' perceived gains in practical competence could be explained by variables in the model. As with the first two models, encouraging contact among students from different economic, social, and racial or ethnic backgrounds was a significant predictor of engineering students' gains in practical competence ($B = 0.33$, $p < 0.01$).

To summarize the regression results, encouraging contact among students from different economic, social, and racial or ethnic backgrounds was the only statistically significant diverse interactions predictor in each of the final models. Tables 3 to 5 present the regression results from the present study.

Table 3: Regression results predicting gains in personal and social development

	Step 1			Step 2		
	Unstd. β	*SE*	*Stand. β*	*Unstd. β*	*SE*	*Stand. β*
(Constant)	78.87	22.21		41.52	22.54	
Race - Recoded (White and Non-White)	3.45	6.55	0.05	5.84	6.38	0.09
Sex	-3.55	4.76	-0.07	-4.83	4.39	-0.10
Age	-9.10	3.79	-0.36*	-6.98	3.62	-0.27*
College classification	1.83	2.26	0.12	3.22	2.17	0.21
Enrollment status	-6.77	9.56	-0.07	-6.11	9.00	-0.06
Grades	-1.06	1.35	-0.08	-2.04	1.31	-0.15
Diverse perspectives in class discussions or writing assignments				1.87	2.26	0.08
Serious conversations with students of a different race or ethnicity than your own				-1.74	3.02	-0.07
Serious conversations with students who are very different from you in terms of their religious beliefs, political opinions, or personal values				-0.01	2.85	-0.00
Better understand someone else's views by imagining issue from his or her perspective				3.85	2.57	0.16
Relationship with other students				0.52	1.82	0.03
Encouraging contact among students from different economic, social, and racial or ethnic backgrounds				9.41	2.21	0.43**

NOTE: $^{*}p < 0.05$, $^{**}p < 0.01$

Table 4: Regression results predicting gains in general education

	Step 1			Step 2		
	Unstd. β	*SE*	*Stand. β*	*Unstd. β*	*SE*	*Stand. β*
(Constant)	50.65	23.04		14.27	24.22	
Race - Recoded (White and Non-White)	-3.12	6.85	-0.05	-2.17	6.84	-0.03
Sex	1.34	4.97	0.03	0.75	4.72	0.02
Age	-7.11	3.96	-0.27	-4.37	3.90	-0.17
College classification	4.30	2.37	0.27	5.21	2.34	0.32*
Enrollment status	6.90	10.02	0.07	6.79	9.69	0.07
Grades	0.22	1.36	0.02	-0.26	1.33	-0.02
Diverse perspectives in class discussions or writing assignments				2.63	2.40	0.11
Serious conversations with students of a different race or ethnicity than your own				1.53	3.24	0.06
Serious conversations with students who are very different from you in terms of their religious beliefs, political opinions, or personal values				-3.93	3.03	-0.16
Better understand someone else's views by imagining issue from his or her perspective				4.92	2.74	0.19
Relationship with other students				0.45	1.96	0.02
Encouraging contact among students from different economic, social, and racial or ethnic backgrounds				7.43	2.37	0.33**

NOTE: $^{*}p < 0.05$, $^{**}p < 0.01$

Table 5: Regression results predicting gains in practical competence

	Step 1			Step 2		
	Unstd. β	*SE*	*Stand. β*	*Unstd. β*	*SE*	*Stand. β*
(Constant)	27.27	22.39		-11.95	22.41	
Race - Recoded (White and Non-White)	-4.61	6.66	-0.07	-8.39	6.33	
Sex	3.33	4.83	0.07	2.56	4.36	0.05
Age	-5.57	3.85	-0.21	-2.64	3.61	-0.10
College classification	3.75	2.30	0.23	3.94	2.16	0.25
Enrollment status	16.0	9.74	0.16	17.9	8.97	0.18
Grades	2.09	1.33	0.15	1.83	1.24	0.13
Diverse perspectives in class discussions or writing assignments				-2.04	2.22	-0.09
Serious conversations with students of a different race or ethnicity than your own				5.69	2.99	0.23
Serious conversations with students who are very different from you in terms of their religious beliefs, political opinions, or personal values				-2.45	2.81	-0.10
Better understand someone else's views by imagining issue from his or her perspective				5.00	2.54	0.20
Relationship with other students				-0.46	1.82	-0.03
Encouraging contact among students from different economic, social, and racial or ethnic backgrounds				7.54	2.20	0.33**

NOTE: $^{*}p < 0.05$, $^{**}p < 0.01$

Limitations

As with all social science research, this study was not without limitations. One limitation of the model was the relatively small sample size (*N*=115). This dramatically reduced the number of undergraduate engineering students of color in the analysis. For this reason, we use an aggregated sample (i.e., "students of color/non-White") to analyze data by race, which might have influenced our ability to detect statistically significant differences by race. Results should be interepreted with this in mind.

Another limitation of this analysis is associated with use of self-report data for all of the perceived learning gain outcome measures. Rather than objective measures of students' actual skills and abilities, the study's instrument asked students to estimate the degree to which they've learned or grown in specific domains (e.g., critical thinking) over the last year in college. A good deal of research debates the reliability and validity of self-report data from college students. While open to critique, self-report measures have been used extensively in social science research and have demonstrated validity with objective measures and adequate reliability over time for some sample. [15] Still, findings should be interpreted with these considerations in mind.

Discussion

The purpose of this study was to estimate the educational benefits that accrue to undergraduate engineering students who interact with diverse peers and perspectives. We conducted multivariate analyses on multi-institutional survey data from 115 engineering students at 4-year campuses to answer the following: (a) What are the mean perceived learning gains of undergraduate students in engineering? (b) Are there differences in mean perceived learning gains of undergraduate engineering students by race/ethnic or gender? (c) What is the relationship between diverse perspectives and undergraduate engineering students' perceived learning gains, controlling for confounding factors? Results suggest several important conclusions.

First, our results suggest that encouraging contact among engineering students from different economic, social, and racial or ethnic backgrounds likely leads to greater learning gains in domains such as personal/social development, practical competence, and general education. We found that campus conditions or encouraging student contact across diversity influences student perceived learning gains, which lends empirical support to Astin's I-E-O model that grounded our study. These findings also resonate with previous research on the educational benefits of diversity—interactional diversity seems to promote desired gains for students. Information of this kind may be useful for Court decisions (e.g., *Fisher* case in Texas) and decisions by engineering deans, UEP directors, and faculty members about building environments that produce learning in students.

Second, students' year in college and enrollment status were also found to be statistically significant predictors of perceived learning gains in general education and practical competence respectively. The first may reflect a long-standing belief in higher education—that students gain from every year spent in college; thus, senior engineering majors would be expected to report greater gains than their freshman and sophomore peers. That full-time students report higher perceived gains in practical competence than their part-time peers may seem rather intuitive; those who attend college full-time, taking more credits, and more courses have more opportunities to learn and utilize skills such as critical thinking and effective communication. Similarly, these results may reflect aspects of Astin's I-E-O model and his involvement theory—by investing more time and energy in the college experience, full-time engineering majors gain more.

Based on these findings, we offer the following recommendations. UEPs should focus on encouraging student collaboration and interactions with others who are of different economic, social or racial/ethnic backgrounds. First, engineering programs can target a diverse student body through increased outreach programs and recruitment. Student collaboration can occur through in-class assignments, extra-curricular academic programming designed for engineering students, and social events. Another suggestion is the use of formal programs such as mentor-mentee pairings amongst freshman and senior engineering students, living learning communities, and student design teams that not only facilitate meaningful engagement among engineering students but also signal to students that the university and/or UEP encourage such involvement. These interactions can both improve reported student learning gains, but also foster a sense of belonging within programs. This added benefit might also promote students' persistence within engineering. As such, it holds particular promise for women and underrepresented minorities who are traditionally marginalized in engineering fields.

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