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Cultural Diversity in Undergraduate Engineering Education

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Abstract

The primary objectives of this study were to assess engineering students' and professional engineers' perceptions of cultural diversity in undergraduate engineering course curriculum, gender and ethnicity-specific access to the engineering field, and the professional engineering work environment in the United States. The sample consisted of 132 undergraduate engineering students and 90 professional engineers residing in the southern part of the U.S. The participants completed two survey questionnaires. Findings suggest that both the students and engineers responded similarly about the importance of having cultural diversity courses in the engineering program. However, students perceived to a greater degree than engineers did that all qualified students have equal access to an engineering education in the country. Students noted more than engineers that the existing curriculum accentuates cultural diversity and engineering programs need to recruit more minority students. Compared to their professional counterparts, students showed a stronger belief that engineers must maintain a high level of work ethics, tended to experience high levels of job satisfaction, and were well paid.

Keywords: students' perceptions, access to engineering education

Introduction

The present study explores the extent to which undergraduate engineering students and professional engineers perceive the importance of cultural diversity courses in undergraduate engineering education, gender and ethnicity-specific access to the field, and the professional engineering work environment in the United States. It has been widely observed that the undergraduate engineering curriculum includes very limited courses on cultural competency and the engineering student population itself lacks diversity. Although nearly 30% of the current U.S. population is comprised of African-American and Hispanic American individuals, these groups represent less than 6% of science and engineering students in the country (Rosenman, 2010). However, the presence of non-U.S. students in American colleges and universities somewhat helps to diversify engineering students in the U.S. During the 2016-2017 academic year, an estimated 1.08 million international students attended U.S. institutions of higher learning (Institute of International Education, 2017). Approximately 39% and 11% of these international students were enrolled in science and engineering programs, respectively. The top 10 countries that sent science and engineering students to the U.S. were China, India, South Korea, Saudi Arabia, Nepal, Japan, Turkey, Mexico, Canada, and Taiwan (Burreli, 2010; Redden, 2018). Many of these international students become U.S. immigrants who encourage their children to pursue science and engineering studies. The increasingly global nature of the professional engineering field, coupled with the presence of these students from diverse social and economic backgrounds, underscores the necessity of cultural competence courses and training in U.S. engineering education.

Science and engineering curriculum has traditionally been a rigorous and significant component of undergraduate education in both developed and developing nations. The commonalities in scientific theories and methodologies (e.g., positivist philosophy) have been instrumental in developing a globally uniform undergraduate engineering curriculum. This curriculum always emphasizes technical knowledge and its scientific application (Hoshino & Sanders, 2007). Given the scientific and technical achievement and generalization focus of the field, engineering students may have limited educational opportunities to develop cultural acumen in their field.

Since the Industrial Revolution, the positivist scientific notion has dominated nearly all academic discussions about human learning. The positivist approach argues for one universal pathway to the attainment of knowledge. Scholars contend the introduction of mechanized agriculture, mining, and textiles in the 18th century produced profound social, cultural, and economic impact on people's lives. Consumed by universal theoretical formulations and principles of scientific development, engineers across the world started to build mechanical devices to produce goods and services. In the early days of mechanized engineering, individuals had little time to examine the cultural ramifications of their innovations, as they needed to focus on perfecting devices and serving limited populations. However, during the 20th century, knowledge of cultural diversity became an increasingly valued commodity. Arguably, the notions of resilient psychology and diversity in education have emphasized the importance of cultural context in scientific innovations vis-à-vis the development and application of human knowledge.

Although contemporary engineers and engineering students lack gender and cultural diversity, they must perform work in a globalized economy with varied ecosystems (Chang & Wang, 2011). Scholars (Herbeaux & Bannerot, 2003) argue it is important for engineers to design products, which maintain the cultural aesthetics for particular consumer groups. In the current global economy, it is often possible that an American engineer will design and build certain products for non-American consumers. For example, U.S.-manufactured chopstick rests with Japanese cultural accents make the product very popular among the Japanese people (Herbeaux & Bannerot, 2003). Cultural awareness equips engineers to understand, innovate, and market certain products successfully. In general, students across disciplines develop multicultural competence through exposures to multicultural courses and intergroup dialogues (Lopez, 2004; Smith, Parr, Woods, Bauer, & Abraham, 2010). Therefore, there are calls for developing integrated engineering curricula that will provide students opportunities to establish interdisciplinary platforms and diverse community networks (Froyd & Ohland, 2005).

Despite the STEM (Science, Technology, Engineering, and Mathematics) initiatives to recruit minority and female students in science and technology, the gender gap in the engineering field is also quite visible. In the U.S., only one-fifth of the engineering students are female (National Science Foundation, 2000) and approximately 11% of the nation's engineers are women (Frehill, 2010). This trend in skewed gender distribution is echoed in the engineering profession around the world. Traditionally, male students believe female students are less talented than male students and female students are less likely to be successful in engineering (Carpenter, Harding, Finelli, Montgomery, & Passow, 2006; Meinholdt & Murray, 1999; Powel, Bagilhole, & Dainty, 2009).

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Such male domination and the widespread anti-women view contend that intellectual growth is *fixed* and not malleable (Dweck, 1999). The implication of this belief is that engineering is a difficult academic field and female students are at risk of failure for their lack of efficacy. Reports suggested female engineering students experienced more negative stereotypic treatment than did male engineering students (Heyman, Martyna, & Bhatia, 2002). Furthermore, findings from Heyman et al. study suggested female students often faced inhospitable academic environments and that they felt compelled to work harder than their male peers in order to achieve success. The hostile and paternalistic belief structure and discriminatory academic environment against women continue to sustain the gender gap in the field across societies.

There are indications that different communication styles create gender-specific pathways for student learning and success. For example, male and female engineering students approach problems differently. Whereas female students are at ease handling complex and ambiguous problems, male students are more comfortable solving a single, concrete problem (Rosser, 1990). Similarly, students from cultural minority groups may approach a science or engineering problem in relation to their own cultural beliefs and natural ecologies. For example, Navajos in the United States relate geographic land formations and natural resources to their families, clan relations, and spiritual practices (Ricehmann, Wadsworth, & Deyhle, 2004). This example implies knowledge about cultural beliefs and practices help equip an engineer to work effectively with American Indians who subscribe to the notion that natural calamities are an act of disharmony between humanity and the environment. Therefore, it is critical to explore how both engineering students and professional engineers in the U.S. view the presence of gender and cultural diversity in engineering education.

Minority students in the United States typically have limited access to the engineering field. Whereas 36% of the U.S. population is non-white, members of ethnic minority groups represented about 10% of the American science and engineering labor force in 2006 (*The Chronicle of Higher Education*, 2010). Although pre-college math preparation is an important indicator for admission to science and engineering programs, a student's social and economic conditions have a significant impact on access to engineering education (Freeman, 2010). Challenging factors such as economic poverty, school dropout rate, and proper academic counseling severely hamper non-Asian minority students' academic preparation as well as admission into engineering programs (Betz, 1997). Schaefer (2015) demonstrated minority students are motivated to do well at school, but they frequently lack resources to successfully complete their college educations.

Findings from prior research suggested approximately 20% of employed engineers in the U.S. were highly satisfied with their current jobs (Frehill, 2010). This report further suggested that whereas male engineers were more satisfied than their female counterparts in chemical engineering, both male and female engineers in civil, electrical, and mechanical engineering were equally satisfied with their jobs. It appeared that the level of job satisfaction for both male and female engineers markedly improved when they accepted non-engineering jobs. In general, a large majority of female engineers viewed their work environments as inequitable due to discrimination along gender lines. Because of the lack of research in diversity in engineering education and the growing diversity in American society, we need to conduct an empirical investigation to understand the contexts of cultural, curricular, and gender-specific diversity in the fields of science and engineering education. The current study is a step toward that effort.

Objectives of the Study

The specific research questions of the present study were as follows:

1. Do undergraduate engineering students and professional engineers differ in their perceptions of the importance of cultural diversity courses in undergraduate engineering education curriculum, levels of gender specific and minority access to the program, and the state of work environment for engineers?

2. Are there relationships between the engineering students' and professional engineers' perceptions of the importance of cultural diversity courses in engineering programs, access to the program, and work environment with the respondents' socioeconomic variables such as age, education, and income?

Methods

Participants

The participants of the study consisted of 132 undergraduate engineering students and 90 professional engineers with a Bachelor of Engineering degree. The students were pursuing an undergraduate degree in mechanical and electrical engineering at a university located in the South of the United States. All student participants came from five engineering classes at the university and their class standing ranged from freshmen to senior levels. The engineers were employed at 10 different industries within 90 minutes driving distance from the main campus of the university. While working full-time, a few engineers ($n = 10$) were pursuing a graduate degree in engineering at the selected university at the time of survey. About 90% of the engineers agreed to participate in the study. The average age for participating engineering students and professional engineers was 21.06 ($SD = 3.71$) and 36.82 ($SD = 11.67$) years, respectively. Engineering students and professional engineers had completed 14.86 and 16.96 years of education, respectively. Whereas an overwhelming majority of the participants had middle-income family backgrounds, approximately 20% of the engineering students and nearly 7% of the engineers had low-income family backgrounds. About 91% of the student and engineer participants were males. Furthermore, more than 80% of the participants in both samples were Euro-Americans and about 20% were from Asian and African American ethnic backgrounds.

Sample and Data Collection Procedures

Engineering students were identified and selected through five engineering faculty who were teaching undergraduate classes at the time of survey. After establishing initial contacts with the five engineering faculty, the first author, who also worked at the university, went to their classes to personally recruit the potential student participants and administer the questionnaires. In each classroom, the first author briefly described the study and the participant student's role in it, explained the voluntary nature of their participation, and read the consent letter to them. All contacted students volunteered to participate in the study. Once informed consent was obtained, the researcher distributed the prepared questionnaires among the students and advised them to fill them out without consulting others in the classroom. On average, it took about 20 minutes for each student to complete the questionnaires. Using engineering work-related and personal contacts, a list of 100 engineers employed at 10 engineering industries located near the university was prepared. The study questionnaires with an introductory letter describing the purpose of the study,

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requesting their participation in the study, and explaining the procedures to complete the questionnaires were sent to these 100 potential engineer participants. Each participant received an envelope with the return mailing address and adequate stamps on it. Ninety of the 100 contacted engineers returned the completed package within four months resulting in a high response rate. It may be worthwhile to mention that much of the empirical research on various psychological issues have relied on participants' self-reports with success (Marsiglio, Amato, Day, & Lamb, 2000; Wical & Doherty, 2005). In addition, the institutional review board of the university approved the study protocol.

Measures

Sociodemographic Questionnaire

The researcher-developed sociodemographic questionnaire contained 7 items concerning participants' age, gender, number of years of education completed including level of college year for the students, marital status, ethnicity, and family income background.

Cultural Diversity in Undergraduate Engineering Education Questionnaire (CDUEEQ)

There is a lack of standardized instruments to measure students' perception of cultural diversity in engineering education and curriculum. Therefore, the authors developed the CDUEEQ to assess engineering students' and engineers' perceptions of cultural diversity in the undergraduate engineering education program. The CDUEEQ has 11 items organized into three different diversity-related aspects of undergraduate engineering education.

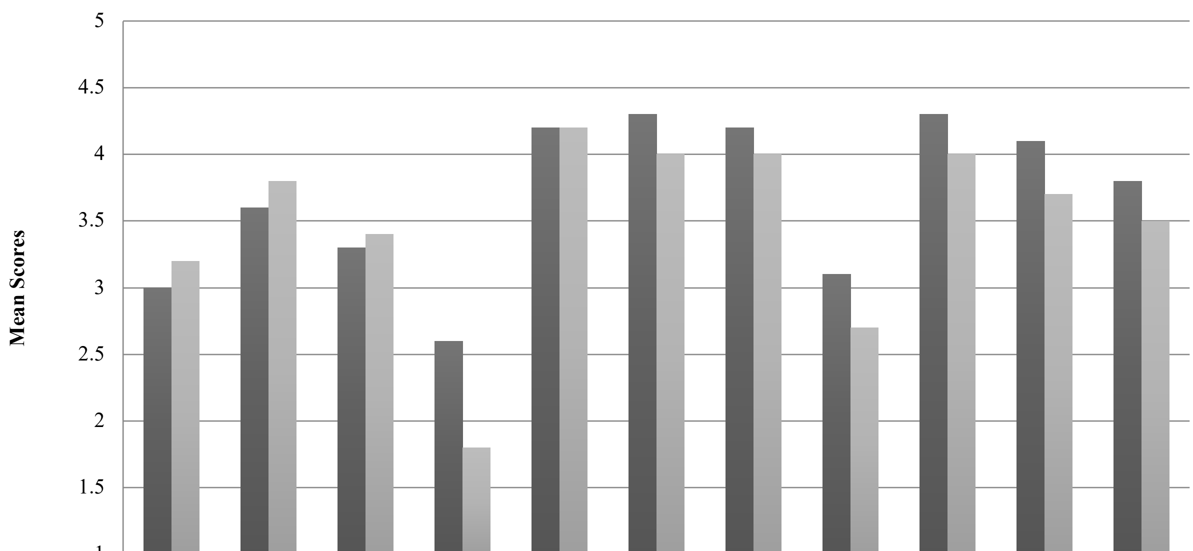
The first area explores the *importance of cultural diversity courses in undergraduate engineering program*. This section includes four items as follows: it is important to include cultural diversity courses in core undergraduate engineering education curriculum, it is important for engineering professionals to understand cultural diversity contexts at work, the engineering labor force in the United States is diverse, and the core engineering curriculum includes courses in cultural diversity. The second area examines *access to undergraduate engineering program*. This section includes four items as follows: academically qualified both male and female high school graduates have equal access to undergraduate engineering programs in the US; most students in undergraduate engineering education programs across campuses are male students; academically qualified both white and non-white high school graduates have equal access to undergraduate engineering education; and American universities should admit more minority students in their undergraduate engineering education programs. The third section reflects aspects of *work ethics and job satisfaction of engineering professionals*. This section includes items such as engineering professionals maintain a high level of work ethics, engineering professionals are well paid, and job satisfaction among employed engineers is high.

Each item was rated from 1 (strongly disagree) through 5 (strongly agree). Whereas the reliability coefficients (i.e., Cronbach α) for all 11 items was .79 for engineering students and .57 for engineering graduates, the Cronbach α for the entire sample was .74. Prior to finalizing the questionnaire to collect data, the pre-test of the questionnaire with two undergraduate engineering students and one engineer was conducted to gauge its applicability to the study sample (Van De Vijver & Leung, 1997). These responses indicated participants were comfortable with the questionnaire items. The pre-test participants were not included in the study.

Findings

Overall Response Patterns in Perceptions

To explore the degree to which undergraduate engineering students and professional engineers perceived the importance of having cultural diversity courses in the engineering education curriculum, the level of access to the program, and the work environment of engineers, the authors first calculated the means of each of the 11 question items by each group. The descriptive statistics (i.e., mean) showed that with a few exceptions, the respondents in both groups agreed highly with the question items in the access category followed by work environment and importance of cultural diversity courses in the engineering education program (Figure 1). There appeared to be a similar pattern in engineering students' and professional engineers' overall responses to all 11 variables. However, respondents showed the least agreement with the statements of *core engineering curriculum includes cultural diversity courses* and e*ngineering program should recruit more minority students*.



	Courses	Work	Labor	Curricu	Access	Composi	AccessM	Recruit	Ethics	Pay	Satisfac
Student	3	3.6	3.3	2.6	4.2	4.3	4.2	3.1	4.3	4.1	3.8
Engineer	3.2	3.8	3.4	1.8	4.2	4	4	2.7	4	3.7	3.5

Figure 1. Mean scores of cultural diversity variables by engineering students and professional engineers (Rating scale: 1 = Strongly Disagree, 5 = Strongly Agree)

Group Differences in Response Patterns

Importance of Cultural Diversity in the Engineering Education Curriculum

Independent *t* tests were employed to examine whether engineering undergraduate students and professional engineers in the current sample differed in their perceptions of the importance of cultural diversity courses in the engineering undergraduate curriculum. As indicated earlier, the importance of cultural diversity measured four areas: views toward including diversity courses in the core curriculum, cultural diversity at work, diversity in engineering labor force, and the presence of cultural courses in the existing curriculum. The analyses revealed that engineering undergraduate students and engineering graduates did not differ in their perceptions toward

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including cultural diversity courses in the core curriculum, t (220) = -0.94, p = .35; understanding cultural diversity at work, t (220) = -1.23, p = .22; and diversity in the engineering labor force in the United States, t (220) = -0.61, p = .55 (Table 1). However, undergraduate students scored significantly higher than did professional engineers rating the statement of whether their existing curriculum included cultural diversity courses, t (220) = 5.17, p = .00.

Access to Undergraduate Engineering Program

Independent *t* tests were conducted to assess whether engineering students differed from engineers in their perceptions of access to the engineering education program. Access to engineering education measured four areas as follows: male and female students' accessibility to the program, sex distribution of the students enrolled in the program, ethnicity and access to the program, and recruiting more minority students in the program. Analyses revealed that students' and engineers' perceptions about students' accessibility to the program did not differ in terms of students' sex, t (219) = 0.45, p = .66; and ethnicity, t (218) = 1.03, p = .31 (Table 1). However, students scored significantly higher than engineers concerning whether the engineering field is dominated by male students, t (218) = 2.57, p = .01, and whether there was a need to recruit more minority students in the engineering education program, t (220) = 2.82, p = .01.

Table 1. Importance of Cultural Diversity Courses in Undergraduate Engineering Program, Access to Engineering Program, and Job Satisfaction

	Engineering Students (n = 132)		Professonal Engineers (n = 90)				
Variables	**Mean**	***SD***	**Mean**	***SD***	***t***	***df***	***p***
Importance of Cultural Diversity Courses							
Important to include cultural diversity courses	3.07	1.07	3.21	1.17	-0.94	220	.35
Important to understand cultural diversity at work	3.64	0.99	3.81	0.99	-1.23	220	.22
U.S. engineering labor force is diverse	3.34	1.06	3.42	0.99	-0.61	220	.55
My curriculum includes cultural diversity courses	2.56	1.03	1.81	1.09	5.17	220	.00
Access to Undergraduate Engineering Program							
Male and female students have equal access	4.24	1.07	4.18	1.13	0.45	219	.66
Engineering program is dominated by male students	4.32	0.98	3.97	1.04	2.57	218	.01
White and non-white students have equal access	4.18	1.09	4.03	1.02	1.03	218	.31
Need to recruit more minority students in engineering	3.07	1.11	2.66	1.02	2.82	220	.01
Work Ethics and Job Satisfaction							
Engineers maintain a high level of work ethics	4.29	0.95	4.02	0.85	2.13	220	.03
Engineers are well paid	4.07	0.92	3.67	0.69	3.53	220	.00
Job satisfaction among engineers is high	3.83	0.99	3.53	0.71	2.45	218	.01

Work Ethics and Job Satisfaction

To understand the difference in engineering students' and engineers' perceptions of work ethics and job satisfaction, independent *t* tests were conducted on three variables: salary of engineers, job satisfaction of engineers, and work ethic among engineering professionals. Analyses revealed that students scored significantly higher than engineers in their perceptions of whether engineers are highly paid, t (220) = 3.53, p = .00; level of their job satisfaction, t (218) = 2.45, p = .01; and their work ethic, t (220) = 2.13, p = .03. These results are presented in Table 1.

Links between Perceptions and Socioeconomic Variables

Regression analyses were performed to tease out the socioeconomic predictors (age, education, and income) of engineering students' and professional engineers' perceptions of the importance of cultural diversity, access to the program, and work environment. In view of the small sample size, we needed to reduce the 11 measured variables into a few coherent variables. By combining item scores to create a single cultural importance, access, or work environment score results in a uni-dimensional dependent variable and facilitates multivariate tests with more statistical power (Pedhazur & Schmelkin, 1991).

Prior to conducting regression analyses, the four cultural importance variables were collapsed into one variable termed *cultural importance*. The decision to create a single cultural importance score from the four cultural importance items is consistent with the fact that these four categories of cultural importance are somewhat a related concept. This association was further evidenced by the low to moderate correlation among these four items as the inter-correlation coefficients (r_s) ranged between .17 and .27. Similarly, the four access items to the engineering program variables convey somewhat a related concept of *access* to the undergraduate engineering education program. The correlations among these four access items were moderate (but not significant) and the inter-correlation coefficients ranged between .20 and .24. Likewise, three items related to work ethics and environment variables were collapsed into one variable termed *work environment*. The inter-correlations among these three variables were low to moderate. Overall, six separate multiple regression analyses were conducted to examine the relative impact of each of the sociodemographic variables on the three dependent variables (i.e., cultural diversity, access, and work environment) for student and engineer groups.

For engineering students, age was negatively associated with their perceptions of work environment (β = -0.24, p = .01). In other words, younger students rated the condition of work environment better than the older students did. This model was marginally significant and explained 6% of the variance, F (3, 119) = 2.47, p = .06). For professional engineers, age (β = -0.23, p = .04) and education (β = -0.29, p = .00) were negatively significantly associated with their perception of access to engineering education. It means younger engineers with fewer years studying perceived higher access to engineering programs than older engineers with more number of years in education did. This model explained 12% of the variance, F (3, 81) = 3.82, p = .01. The results are presented in Table 2. The importance of cultural diversity was not related to any of the three socioeconomic variables for these two groups.

Table 2. Multiple Regression Equations for Engineering Students and Professional Engineers' Perceptions of the Importance of Culturally Diverse Curriculum, Access to Engineering Education, and Work Environment for Engineers

Participant Groups	R^2	F	df	B	$SE\ B$	β	p
Engineering students							
Dependent variable = Work environment	.06	2.47	3.119				.06
Age				-0.05	0.02	-0.24	.01
Education				-0.01	0.01	-0.4	.66
Income				-0.06	0.14	-0.04	.69
Professional engineers							
Dependent variable = Access	.12	3.82	3.81				.01
Age				-0.01	0.01	-0.23	.04
Education				-0.13	0.05	-0.29	.00
Income				0.08	0.26	0.03	.76

Discussion

The primary objective of this study was to determine the extent to which undergraduate engineering students and professional engineers perceived the importance of cultural diversity in

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undergraduate engineering education, level of gender and ethnicity-specific access to the field, and the professional engineering work environment in the United States. Furthermore, the study explored the links between students' and engineers' perceptions of cultural diversity in the engineering curriculum, access to the engineering program, and engineering work environment with respondents' socioeconomic variables such as age, education, and income.

The results of the study indicated that both engineering students and professional engineers believed the attainment of cultural competency is a valuable aspect of engineering curriculum. In general, there was a consensus between students and engineers that cultural diversity should be an important component of undergraduate engineering education. Although both groups agreed courses on cultural diversity were not emphasized in the undergraduate engineering curriculum, the students reported significantly more than professional engineers that their curriculum did include courses on cultural diversity. These results suggest a reversal of the trend that engineering students have had scarce opportunities for training in cultural diversity (Hoshino & Sanders, 2007). This shift may be paradigmatic of changing attitudes in higher education as pluralism has become an increasingly embraced ideal in the United States. It may also indicate the presence of international students in American engineering education programs is positively influencing the prospects of having cultural diversity courses in undergraduate engineering curriculum (Fischer, 2009; Burreli, 2010). It can be argued that because of the presence of international students and the diverse ethnic composition of the U.S. population, American colleges have possibly adapted their curriculum to serve their increasingly diverse student populations. This is a good start and the supposition is congruent with previous research has argued for the multi-cultural training of engineering students in the U.S. (Herbeaux & Bannerot, 2003).

The study also found engineering students tended to have paradoxical beliefs about access to an engineering education. To a significantly greater degree than their professional counterparts, students reported that all qualified individuals have equal access to the undergraduate engineering program. However, compared to engineers, students scored higher expressing that engineering programs should actively recruit more minorities. These seemingly incompatible views may reflect personal observations pertaining to the success of minority students once they are admitted to an engineering program. Previous research has demonstrated that ethnic minorities face multiple barriers to accessing engineering programs (Freeman, 2010), but that once enrolled, minority students are highly motivated to be successful (Schaefer, 2015). We speculate the present findings indicate engineering students' lack of knowledge about entry barriers for minorities. The findings also suggest a strong degree of confidence in the abilities of minority students once admitted to an engineering program. These findings are in line with the current nationwide STEM effort to recruit female and minority students in the engineering education program.

Furthermore, the results of the study revealed engineering students demonstrated a more positive assessment of professional engineers' lifestyles than did professional engineers. Students and engineers differed in their perceptions of pay, job satisfaction, and ethics. Compared to engineers, students consistently perceived engineers received a high salary, maintained a high level of job satisfaction, and had high ethical standards in the workplace. These findings perhaps indicate that the engineers' perceptions of these areas have been moderated by their *real-world* experiences on the job. It is possible students' sense of expectation and idealism about the engineering profession is different from what engineering professionals experience at work. This finding is in accord with previous research indicating that engineers report a low level of job satisfaction which increases when they take employment in non-engineering settings (Frehill, 2010). Future empirical research is needed to investigate why professional engineers feel less satisfied in the work place.

With reference to correlational analyses, younger engineering students perceived a more optimistic work environment than the older students. It is possible graduating high school seniors observe a very successful occupational and economic lifestyle of professional engineers. Many of these students enter the engineering education program with a lot of enthusiasm and expectations of professional success. They envisage their future professional life and employment opportunity in a positive way. Likewise, younger professional engineers perceived access to engineering education was (or should be) more equitable across ethnicity and gender lines than their older counterparts. This finding can be attributed to the fact that the contemporary generation is well exposed to the diverse ethnic and gender contexts of American society. The presence of noticeable numbers of international students and professionals in American schools and work places may sway contemporary young professional American engineers to be cognizant about equitable access to engineering education. However, the negative correlation between professional engineers' education and their perception of access to engineering education is somewhat difficult to explain. The level of education of professional engineers in our sample was very high for some participants who were also pursuing a graduate degree in engineering. Such a variation in education may have caused this sample truncated on education resulting in a negative correlation between education and access. Future research with a larger sample could investigate this issue.

In sum, both professional engineers and engineering students agreed on the importance of cultural diversity in the engineering program. Although professional engineers and engineering students differed on issues related to salary, job satisfaction, and ethics and work environment, the current findings signal a need to evaluate the influence of socioeconomic and other relevant (e.g., personal motivation, work demand) variables on the context of engineering education curriculum and the profession. To conclude, engineering students and professional engineers appeared to recognize the value of cultural competency in both the classroom and workplace settings. Respondents acknowledged the increasingly diverse nature of the engineering profession. Furthermore, the responses reflected a growing desire for entertaining various aspects of cultural diversity in a field which has traditionally excluded culturally diverse curriculum, student body, and training in its undergraduate programs. The findings of the current study enrich the education literature and embolden the critical debate of diversifying engineering education in the United States. The engineering program must address the lack of cultural and gender diversity in its curriculum.

Implications

Several significant implications arise from this study. Both engineering students and professional engineers concede cultural diversity is present both in the classroom and in the workplace, but there are limited opportunities for developing cultural competency in undergraduate engineering education. This signals a critical need for engineering programs to incorporate diversity training into their curricula (Froyd & Ohland, 2005). The benefits of doing so could stretch beyond measure. First, engineering students would greatly benefit from a shift in coursework which is taught from a *critical* viewpoint rather than from the traditional positivist pedagogy. This change would foster the development of critical thinking skills, enhance the ability to analyze data from various perspectives, and would encourage students to reason through problems within the wider global context. Second, the incorporation of diversity training into engineering programs should promote collaboration between students from various cultural, social, and economic groups—a trend which hopefully would be echoed in the professional engineering world. This could bolster students' abilities to cooperate with individuals from various backgrounds and prepare them for the increasingly global nature of the workforce (Coyle, Jamieson, & Oakes, 2006). Third, a cultural diversity component of engineering education would move engineering students from

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specificity in their chosen disciplines towards general knowledge of the field, perhaps with an inter-disciplinary perspective. Given the highly competitive nature of the current U.S. and global job markets, students who develop expertise in a variety of areas will be better positioned to find employment after graduation. The study's results, coupled with the global nature of the job market, indicate this is a critical time for the development of cultural competency in the engineering profession. We believe the STEM education coalition in the United States is the right approach and step toward that goal.

Limitations and Future Research Directions

This study had several limitations. The first constraint was related to the sample size and the non-random method of selection. The small sample size of undergraduate engineering students (n = 132) and professional engineers (n = 90) taken from a geographically modest area (i.e., within a 90-minute driving radius of the university located in the South) suggests little variation in respondents' educations, socio-economic backgrounds, and professional pursuits. Although the sociodemographic data did indicate some variation in respondents' economic and ethnic backgrounds, the differences were minimal. The entire sample derived from a convenience sampling technique as researchers recruited the respondents through classroom, personal, and professional contacts. In addition, the respondents were primarily Euro-American males. For future studies, the authors recommend the random selection of student and engineer participants from various backgrounds and regions of the U.S., with attention given to the representation of rural and urban environments, public and private colleges, and various disciplines within the engineering field.

Second, the current findings have limited possibilities for generalization. The engineering students' responses reflect upon only two undergraduate engineering programs (i.e., mechanical and civil), as opposed to a variety of engineering programs throughout the U.S. which may or may not emphasize cultural diversity in their curriculums. It would also be challenging to generalize the findings to other academic areas which may or may not embrace pluralism as a benchmark of high scholarship. The authors recommend further research which places engineering students' and professional engineers' perceptions of cultural diversity within a broader spectrum of other math and science disciplines. For instance, future research may compare engineering students' perceptions of cultural diversity with those of physics, geology, biology, or chemistry majors. A meta-analysis of a cultural diversity curriculum in undergraduate math and science programs would provide greater insight into the current climate of cultural diversity in science and engineering education.

References

Betz, N. (1997). What stops women and minorities from choosing and completing majors in science and engineering? In D. Johnson (Ed.), *Minorities and girls in school: Effects on achievement and performance* (pp. 105-140). Thousand Oaks, CA: Sage.

Burreli, J. (2010). *Foreign science and engineering students in the United States*. Retrieved from ERIC database. (ED510865)

Carpenter, D. D., Harding, T. S., Finelli, C. J., Montgomery, S. M., & Passow, H. J. (2006). Engineering students' perceptions of and attitudes towards cheating. *Journal of Engineering Education, 95*, 181-194.

Chang, P., & Wang, D. (2011). Cultivating engineering ethics and critical thinking: A systematic and cross-cultural education approach using problem-based learning. *European Journal of Engineering Education, 36,* 377-390.

Coyle, E. J., Jamieson, L. H., & Oakes, W. C. (2006). Integrating engineering education and community service: Themes for the future of engineering education. *Journal of Engineering Education, 95,* 7-11.

Dweck, C. S. (1999). *Self-theories: Their role in motivation, personality, and development*. Philadelphia, PA: Taylor & Francis.

Fischer, K. (2009). Number of foreign students in U.S. hit a new high last year. *The Chronicle of Higher Education*. Retrieved from http://chronicle.com/article/Number-of-Foreign-Students-in/49142

Freeman, A. L. (2010). Money, math and engineering: The relationships between community economics, math preparation and the graduation of racially underrepresented engineers. *Dissertation Abstracts International Section A: Humanities and Social Sciences*, *70*, 4149.

Frehill, L. (2010). Satisfaction: Why do people give up engineering? Surveys of men and women engineers tell an unexpected story. *Mechanical Engineering*, *132*(1), 38-41. doi:10.1115/1.2010-Jan-4

Froyd, J. E., & Ohland, M. W. (2005). Integrated engineering curricula. *Journal of Engineering Education*, *94*, 147-164.

Herbeaux, J. J., & Bannerot, R. (2003, June). *Cultural influences in design*. In the Proceedings of 2003 Annual Conference of American Society for Engineering Education, Nashville, Tennesse. Retrieved from https://peer.asee.org/cultural-influences-in-design.pdf

Heyman, G. D., Martyna, B., & Bhatia, S. (2002). Gender and achievement related beliefs among engineering students. *Journal of Women and Minorities in Science and Engineering*, *8*, 41–52.

Hoshino, Y., & Sanders, W. (2007). *Promoting cultural awareness and understanding in engineering education curriculum*. Paper presented at the International Conference on Engineering Education, Coimbra, Portugal.

Institute of International Education. (2017). IIE releases open doors 2017 data. Retrieved from https://www.iie.org/Why-IIE/Announcements/2017-11-13-Open-Doors-Data

Lopez, G. E. (2004). Interethnic contact, curriculum, and attitudes in the first year of college. *Journal of Social Issues, 60*, 76-92.

Marsiglio, W., Amato, P., Day, R., & Lamb, M. E. (2000). Scholarship on fatherhood in the 1990s and beyond. *Journal of Marriage and the Family, 62*, 1173-1191.

Meinholdt, C., & Murray, S. L. (1999). Why aren't there more women engineers? *Journal of Women and Minorities in Science and Engineering*, *5*, 239–263.

Pedhazur, E. J., & Schmelkin, L. P. (1991). *Measurement, design, and analysis: An integrated approach*. Hillsdale, NJ: Erlbaum.

Powell, A., Bagilhole, B., & Dainty, A. (2009). How women engineers do and undo gender? Consequences for gender equality. *Gender, Work and Organization, 16*, 411-428. doi: 10.1111/j.1468-0432.2008.00406.x

Redden, E. (2018). International student numbers decline. Retrieved from https://www.insidehighered.com/news/2018/01/22/nsf-report-documents-declines-international-enrollments-after-years-growth

Ricehmann, T., Wadsworth, M., & Deyhle, D. (2004). Cultural identity, explanatory style, and depression in Navajo adolescents. *Cultural Diversity and Ethnic Minority Psychology, 10*, 365-382.

Rosenman, E. T. R. (2010). SEAS struggles to attract minority students. *The Harvard Crimson*. Retrieved from https://www.thecrimson.com/article/2010/10/29/students-seas-engineering-percent/

Rosser, S. (1990). *Female friendly science: Applying women's studies methods and theories to attract science*. London, UK: Routledge.

Schaefer, R. T. (2015). *Racial and ethnic groups*. Upper Saddle River, NJ: Pearson.

Smith, H., Parr, R., Woods, R., Bauer, B., & Abraham, T. (2010). Five years after graduation: Undergraduate cross-group friendships and multicultural curriculum predict current attitudes and activities. *Journal of College Student Development, 51*, 385-402.

The Chronicle of Higher Education. (2010). Report calls for doubling of minority students earning science and engineering degrees. Retrieved from http://chronicle.com/blogs/ticker/report-calls-for-doubling-of-minority-students-earning-sc

Van De Vijver, F., & Leung, K. (1997). Methods and data analysis of comparative research. In J. W. Berry, Y. P. Poortinga, & J. Pandey (Eds.), *Handbook of cross-cultural psychology* (Vol. 1); (pp. 257-300). Boston, MA: Allyn & Bacon.

Wical, K., & Doherty, W. (2005). How reliable are fathers' reports of involvement with their children? A methodological report. *Fathering, 3*, 81-93.

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