

AC 2008-1039: ENGINEERING STUDENTS DEFINE DIVERSITY: AN UNCOMMON THREAD

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Abstract

Diversity has come to mean a lot of different things depending on the context in which it is used and the person using it. As a corporate term, diversity evolved out of the civil rights movement of the 1960s and 1970s. In the 1980s, it served as a means of penetrating the dominant ethos of many institutions that aimed to preserve the white male culture. More recently, diversity has been used to include an array of conditions that represent people who feel disenfranchised and excluded. Following a path of seeming ambiguity, today's engineering students have come to embody diversity as an extension of their home, academic and social environments. The result is a group of students that show indifference to diversity (however defined) and the impact it will have on their professional careers.

Using a 4-year longitudinal mixed method approach, the Academic Pathways Study (APS) investigated engineering skills, education, and identity from the first year through their senior years. Four distinct universities recruited 40 of their students each to participate in the study. This paper shares findings from structured interview data elicited from 94 students during their sophomore year. Grounded theory, an inductive, analytical approach was used to develop the concepts that ultimately informed the research. Data both iterative and inconsistent reveal details about how students define diversity and its impact on their undergraduate academic tenure. Further, we explore the impact that gender and race have on sophomore engineering students' academic experience and engineering identity. Finally, a broad range of divergent and parallel views shed light and provide insights about diversity and its impact on their potential careers as told by a cross section of sophomores from around the United States; yet, these data are not meant to generalize beyond the population from which it was taken. This paper contributes important knowledge to the growing body of literature in engineering education and diversity.

Introduction

Burgeoning research on diversity in engineering consistently reveals that engineering struggles to keep pace with trends in the increasingly growing global marketplace¹. Numerous ideas have been put forth as to why student attrition among some groups in science and engineering is so high. Women and minorities who start their engineering education experience higher attrition rates in matriculation and are far more likely to defect to other fields than their white male counterparts². Critical is the rate and level of preparedness to which women and minorities are exposed that prepares them to succeed in a rigorous engineering program. While other fields like veterinary medicine and the medical field continue to enjoy healthy gains across genders and, albeit a lesser degree, multicultural gains through aggressive recruitment and retention efforts, engineering struggles to achieve and sustain the same momentum³.

For more than twenty years, science and engineering degrees have represented approximately one-third of all baccalaureates awarded, according to the National Science Foundation. In 2002, "women earned more than half of the degrees awarded in psychology (78%), biological/agricultural sciences (59%), and social sciences (55%), and almost half (47%) in

mathematics. However, women received only 21% of bachelors degrees awarded in engineering, 27% in computer sciences, and 43% in physical sciences.” These gaps persist despite the higher average salary (40K+) that newly minted engineers command compared to other new Baccalaureates⁴.

This paper highlights key findings from the structured interviews taken in the second year from engineering students. Data both iterative and inconsistent reveal details about how students define diversity and its impact on their undergraduate academic tenure. Further, we explore the impact that gender and race have on sophomore engineering students’ academic experience. Finally, a broad range of divergent and parallel views shed light and provide insights on the overall impact of diversity in engineering for second year students. The broad demographics included detailed informative accounts about diversity and its impact on their potential careers as told by a cross section of sophomores from around the United States; yet, these data are not meant to generalize beyond the population from which it was taken. Finally, student names used throughout this paper are for ease of reading and were not used as identifiers while participants in this study.

Background: The case for diversity

Diversity means many things to many people. It is a construct evolving out of corporate America’s need to reflect a more diverse, and inclusive workforce, integrate the standard business model, and ultimately level the global playing field. Diversity is evolving. Volumes of diversity research catalog this progression to include differences in gender, age, race, political affiliation, religion, sexual preference...etc. This study will also show an array of definitions of diversity as aforementioned.

In academia, administrators, educators and students continue to grapple with ways to increase sensitivity, enrollment, and ultimately a more diverse pool of engineers. Broadening the pool of engineers is not merely an exercise in futility, it is essential to the integrity, validity, and survival of the engineering field. In 1998, William A Wulf, former president of the National Academy of Engineering (NAE), at the annual NAE meeting said:

Our profession is diminished and impoverished by a lack of diversity. It doesn’t take a genius to see that in a world whose commerce is globalized, engineering designs must reflect the culture and taboos of a diverse customer base. Absent a diverse engineering team, those sensitivities may not be reflected....the range of design options considered in a team lacking diversity will be smaller. It’s that the constraints on the design will not be properly interpreted. It’s that the product that serves a broader international customer base, or a segment of this nation’s melting pot, or our handicapped, may not be found. It is that the most elegant solution may not be pursued. There is a real economic cost to that. Unfortunately it is an opportunity cost. It is measured in design options not considered, in needs unsatisfied, and hence unfulfilled. It is measure in “might have beens,” and those kinds of costs are very hard to measure. That doesn’t change the fact that they are very real and very important. Every time we approach an engineering problem with a pale, male design team, we may not find the best solution. We may not

understand the design options or know how to evaluate the constraints; we may not even understand the full dimension of the problem⁵.

Ten years later, diversity in engineering has experienced inconsistent growth, and in some areas, marked decline rendering Wulf's tenets as relevant today as they were when they were first spoken in 1998. Many studies have investigated reasons for the lack of representation of women and minorities in STEM degree programs^{6,7,8}. A story stemming from an engineering ethnographic study further validates and demonstrates that the playing field in engineering is still not level⁸. Following a path of seeming ambiguity, today's engineering students have come to embody diversity as an extension of their home, academic and social environments⁹. As we have found, the result is a group of students that show indifference to diversity (however defined) and the impact it will have on their professional careers.

Because of its complex factors and sensitive nature, the empirical study of diversity has inherent challenges. Factors such as operationalizing and level of comfort with the subject thwart researchers and subjects alike who often express discomfort when talking candidly about issues related to diversity. To that end, researchers must continue to develop more reliable constructs that empirically measure cross-cutting issues of diversity that can be adapted to the engineering academy. It can be said that Wulf's comments still provoke a national referendum on engineering education inviting sound methodological models that can be applied both for local and national reform in engineering education. This study addresses that need and gap.

Theoretical Framework

William James, one of the founding fathers of modern day psychology contends that theories are tools for exploration and understanding and not answers to questions. Out of grounded theory, a theoretical explanation is offered to explain some of the diversity findings in this paper. Structuralism represents the theoretical underpinning upon which we base the phenomena described in this paper. This paradigm under girds the institutional, gender, and multicultural findings presented.

Structuralism

Structural theorists purport that based on need, organisms (women and minorities) respond to fill gaps in their environment. It further posits that people do not work in a vacuum but rather seek to fill in positions based on societal need and their potential offering¹⁰. That is, people fill in gaps where needed. In engineering, one application of structuralism suggests that specifically women but also minorities are often discouraged by teachers and counselors from taking math and science courses integral for majoring in engineering. These groups are often steered toward more traditional social science courses. Citing, there may be fewer job opportunities in engineering and more viable career paths in the social sciences¹¹.

As an example, the structural perspective suggests that during WWII thousands of women worked in engineering (industrial/engineering) factory jobs to replace men at war. Women worked the bulk of factory jobs to fill a societal gap. Furthermore, it is well documented then and now that women had to work harder and longer for less pay¹². Eventually, men returned

from war facing challenges including fewer job opportunities associated with labor market gaps filled by women, who were now a skilled labor force. These seeds of opportunity spurred a period of rapid change that was the impetus for the women's movement. Before long, affirmative action programs and programs in math and science that addressed the needs of an increasingly diverse workforce ensued. While these strides have increased the number of women and minorities in engineering, these groups have not achieved parity or equal representation in the field of engineering. However, as structuralism suggests, necessity is oftentimes the impetus under which paradigmatic shifts occur. Many of these students represented in this study across demographic segments say, hear, and understand the impact that diversity has on engineering. Women and minorities express how they are capable and positioned to be employed in engineering and are taking the opportunities to be heard. Furthermore, as the local community evolves into a global workforce it calls upon engineering to meet evolving needs. For example, in our study several women alluded to being ready for the challenges that they would face simply because they were women. Similarly, minority groups were clear that their challenges to achieve in the field of engineering were not in the realm of the academy but rather they were in the level of acceptance or non-acceptance that engineering and society held for their ethnic background. Furthermore, others suggested that instead of trying to fight with shifting paradigms, they would prefer to blend into the background instead of fight the ethnic battles. Given their level of assimilation both in physical presentation and in ideals, these students too made a choice.

Methodology

Data were collected as part of a larger study of engineering undergraduate students from four distinct U.S. Universities whom initially enrolled during the 2003-2004 academic year. For the purpose of this study we have ascribed pseudonyms to each institution: A) Technical Public Institution (TPI), a public mid-western university specializing in teaching engineering and technology; B) Urban Private University (UPU), a private Historically Black University mid-Atlantic institution; C) Large Public University (LPU), a large public university in the Northwest U.S.; and D) Suburban Private University (SPU), a medium-sized private university on the West Coast.

Including students from diverse backgrounds was a key element of the research plan. For this cohort of students, special attention was paid to understanding how underrepresented students navigate their initial years in engineering education. This was accomplished by employing over-sampling strategies for gender (male/female) and underrepresented minorities (African Americans, Native Americans, Mexican Americans, Puerto Ricans, other Latino groups) in order to gain information about a broader range of students.

This mixed method study, sponsored by the National Science Foundation, investigates experiences of a single cohort of undergraduate engineering students over 4 years and in their own voices. A major goal was to study persistence in engineering through multiple methods. This paper focuses on data gathered from one on one structured interviews administered at all four campuses. Quantitative and qualitative findings from 94 structured interviews conducted during the spring semesters of their sophomore year are presented hereafter. The close ended responses generated from the interviews were analyzed by using descriptive and inferential

statistics in the SPSS program. The open ended responses were coded and searched for patterns disaggregated primarily along the lines of gender, ethnicity and institution. The primary goal of this paper is to share insights into the role that diversity plays on the educational pathways of undergraduate engineering students. No predisposed definition of diversity was expressed or implied while conducting the research or analysis. When diversity is discussed in this paper, it reflects a non-scripted, but inductively constructed term based on the responses of the sample. The quantitative method gives way to the theoretical limitations that suggest that research only uncovers differences but does not answer questions steeped in research methodology that employ both qualitative and quantitative methodologies. This strength based approach provides metrics to explain what differences exist and also why differences occur along those metrics.

Research Questions

Overall, the larger study investigated four major research questions that would be examined longitudinally. These specific research questions included:

1. How do students' engineering skills and knowledge develop and/or change over time?
2. How does one's identity as an engineer evolve? More specifically, how does student appreciation, confidence, and commitment for engineering change during the undergraduate educational experience?
3. What elements of engineering education contribute to the changes observed in questions 1 and 2? What do students find difficult and how do they deal with the difficulties they face?
4. What skills do early career engineers need as they enter the workplace? Where did they obtain these skills? Are any skills missing?

As common in many large research studies, sub studies will emerge from the vast array of data collected. This paper only reports on data from the sub-study that surrounds how students view diversity. Specific research questions for this sub-study featured below sought to inquire more about undergraduate engineering students' perspectives of diversity.

1. How does this generation of undergraduate engineering students define diversity?
2. How do students classify diversity within their academic settings?
3. How do students perceive that their race and gender impacts their goal of becoming an engineer?

This array of questions did not allow for the researchers to pre-impose a definition of diversity, but rather learn the students' definitions of diversity and later its internal or individual impact. The questions posed in the structured interview protocol directly addressed the research questions for this sub-study.

- What does diversity mean to you?
- To what extent do you consider your school to be diverse?
- Does your gender affect your view of becoming an engineer?
- Does your racial identity affect your views of becoming an engineer?

With the exception of the question, “what does diversity mean to you?” which was totally descriptive, all questions were asked in a closed ended format employing a Likert-type rating scale or a yes/ no scale where appropriate. Following their ratings, students were asked to provide descriptive responses to all questions.

Major Findings

In response to the research questions, the major findings of this study are divided into three primary categories: *Defining Diversity*; *Gender Roles and Identity*; and *Racial Identity*.

Defining Diversity

Students defined diversity in many ways. Several taxonomies and themes emerged from the numerous definitions of diversity provided. Some themes were more familiar or universal, while others were less conventional. Among the familiar was diversity of gender, race, culture, and ideology. Less familiar but also important was diversity of major, geography, socio-economic status, and political affiliation. While this section will not include details about all of them, some of the more prominent patterns will be highlighted here within.

Some students found it easy to define diversity and shared very thoughtful expressions about what diversity meant to them. Definitions were as varied as students’ levels of comfort, ranging from framing diversity in the context of ‘institution type,’ to referencing diversity in the context of culture and ideology. For example, Peter, defined diversity by saying “...*I think diversity means people coming from different cultures...it’s a difference.*” Rhonda, a student attending SPU, used a series of analogies to define diversity and explains “... *Diversity, I know some people have the expression that you have more strings to your harp...I think that’s what diversity is...if you love math that’s great, but you also do other things, say music ... diversity in culture...you learn that it’s not just your culture that’s supreme to everything else. I mean that’s why I come here from [her home country] because I want to know more about this culture. That’s why I’m singing in the gospel choir, I’m one of the few white people there (laughs) but that brings diversity....*”

Other students from SPU found it more challenging to define diversity. Laughing or chuckling during their comments was common for some, exposing a level of discomfort with discussing diversity. That is, Roy, like many others define diversity by sharing “...*ah, diversity means ah, it means, ah, it’s hard to define diversity without diversity (chuckle).*”

Bob and other students from LPU, found defining diversity monotonous and redundant Bob cited, “...*social diversity ...is pounded into our head at every stage of your development....*” Rick said, “...*diversity is one of those ‘buzz words’. I don’t think it’s as important as everyone tries to make it.*” Further, Richard shared “...*diversity...I think that’s the fourth time I’ve heard it this year (laughing)...so I guess diversity is just a bunch of different personalities all in one together.*” In their own words, students outlined an impending generational paradigm shift in diversity. Seemingly diversity has become more of a catch all phrase.

An interesting nuance was that there were some inconsistencies in what students reported quantitatively in the closed ended questions and what they went on to describe qualitatively

through the probing from the open-ended questions. That is sometimes their ratings of very diverse, or diverse were inconsistent with their follow-up descriptions. Consider Tom, from LPU, for example. When asked, “how would you rate your school’s level of diversity”, Tom said, “... *I would say it’s fairly diverse.*” When probed as to why, Tom replied, “*It’s a large school so there’s definitely going to be a difference of opinion. There was evidence of that just today in the [my school] lounge...college republicans are protesting...they’re protesting... admission based on race...now there are these other groups... coming out and sort of doing a counter-protest...I think the school tends to lean more one way than the other. I think ... the college republicans tend to be more in the minority....*” Tom provided testimony describing the conflicting nature of diversity or achieving diversity at his institution but rated it as fairly diverse.

Gender Roles and Identity

Students were asked, to what extent does their gender affect their view of becoming an engineer. Independent samples T-test displayed in Table 1 shows the mean differences in t-scores around the significance of gender and engineering career attainment. Female and male students have differing opinions about the impact that gender has on their becoming an engineer ($t=2.25$, $p=.026$). Having a lack of role models was significantly associated with being female ($t=2.369$, $p=.020$). There were no other significant relationships found. Almost two thirds (63%) of students said that their gender did not affect their views of becoming an engineer.

Table 1
Independent Samples T-Test

	t	Df	Sig. (2-tailed)
Q24. Does your gender impact your views of becoming an engineer	2.259	89	.026*
	2.132	38.913	.039*
Gender equality	1.550	89	.125
	1.130	27.670	.268
Inequality	.411	89	.682
	.386	38.682	.701
Role Models	1.640	89	.105
	1.000	24.000	.327
<i>Lack of Role Models</i>	2.369	89	.020*
	1.445	24.000	.161
Support System	1.550	89	.125
	1.130	27.670	.268
Lack of Support system	1.640	89	.105
	1.000	24.000	.327
Male Dominated Field	1.280	89	.204
	1.197	38.290	.239

****Difference of means between females and males is statistically significant. (P< 05)***

Having a lack of role models emerged as an important finding for the women in this study. Those women, who said that gender does impact their views of becoming an engineer, cited that they were impacted negatively by the “*lack of role models.*”

Organizations like ‘Women in Science in Engineering’ were designed to address the lack of support for women in undergraduate engineering programs. Organizations like this fill gaps and advocate that gender role models are critically important in recruiting and retaining engineering students in undergraduate programs. Hammrich et. al., said that women had a strong affiliation for same gender role models¹³. Lisa, a White student from SPU said it best, “...*there are societies, like Society for Women Engineers...that does help change our perspective on being an engineer ...it’s ‘cause I’m female, because I’m a minority and I’m not used to being like that because I’m a white middle class individual ... it’s hard to become an engineer, it’s real intimidating to be...working for... predominantly all males...it’s kind of a challenge to me, ...I can do this, I can pioneer this and be a female engineer, be just as good as a male engineer.*”

Other sophomores indicated that gender had little to no impact on their education, both females and males voiced many different opinions.

Similarly, male students were equally as vocal about the role gender plays in getting their engineering degree. Some express resentment to policies in place to support women and minorities. For example Martin, from LPU exclaimed, *“...if the females... have an advantage, just because things like affirmative action, you know where they give certain advantages to some minorities, I wonder if it is a disadvantage being the majority?”*

Some women hail as ambassadors of the field and are aware of the gender imbalance. Tina from TPI explained, *“...I think that females are such a low percentage of ...engineers, ... it encourages me to be one of those people to get the word out to have more females... in the field of engineering.”* When asked “Does your gender affect your views of becoming an engineer? 63% of students said ‘no’.” Lyn, from SPU offered a paradoxical perspective on attaining an engineering degree that transcends becoming a female engineer. She confides... *“To some extent, because I know that there aren’t as many female engineers...that... motivates me more...to see if I can really do this.”* Ironically, this student goes on to share that she was committed to the degree but not because she wanted to become an engineer. Her intention is to use the engineering degree to help her *“analyze things”* so that she can better think *“sequentially and logically,”* as she pursues her medical degree. Finally, when asked about how their gender affects their views of becoming an engineer often individuals shared poignant adages reflective of a foregone past. For example, Henry, from SPU exclaimed, *“...It’s more natural for males to be engineers.”*

Racial Identity

Students were also asked to share views about how they believed their racial identity affected their views of becoming an engineer. More than eight in ten (81%) answered “no”, that race had no impact on their engineering aspirations. Joel, a white student from LPU articulates, *“I really don’t think so. I don’t think that is a big deal. I don’t think about it very much.”* Yet, Nathan, an African American from UPU, found it more of a concern. He details, *“...the only thing it affects is who’s gonna employ me...but it doesn’t affect how I feel about being capable...if you know what I’m saying, because I’m black....”*

Carlos, a Hispanic student offered a reflection about how race impacts his becoming an engineer. He exclaims *“...No, maybe if I was like another race...people still tell me I look white...my being Spanish has in ...no way shape or form [affected] anything...so I don’t celebrate Cinco de Mayo or anything...”*

Certain ethnic groups felt a social responsibility or pressure to pursue a degree in engineering. Eddie, a sophomore from TPI, shared: *“... I don’t see...my race being a huge... factor in being an engineer, but...I think that at times since I’m Asian, that I fall into the stereotype of being a smart Asian sometimes, so I think, in that aspect it kind of ... influences, but it doesn’t mean that that’s all that defines why I’m planning to study engineering.”*

William, from UPU exclaimed, “... *Once again I feel like sometimes African-Americans... aren't ... considered to be as... capable ... as far as doing course work and everything it takes to become an engineer. I don't personally feel like that's the truth...*”

Discussion

Utilizing a grounded theory approach this data has uncovered several key issues. First, diversity is defined in many ways by a vast demographic of students. In their own words, students outlined an impending generational paradigm shift in diversity. They shared profound thought provoking data for leaders in engineering to consider as they search for ways to attract and retain more women and minorities in the field. Insights gained from this research can address the needs of a cross section of engineering student populations with careful attention paid to gender, race, culture, and ideological similarities and differences. Although not fully presented in this paper, students often define their academic institutions within the predictable range of how society might label their institution in reference to diverse composition. While diversity has become increasingly complex, creative efforts to engage and support the academy from the student body to professors and the administration should be pursued.

We are reminded of the importance of the existence of social supports and positive social relationships in an institution and its integral purpose of maintaining and advancing students' success. Female students in this study expressed an interest and appreciation for programs aimed at recruiting and retaining women. Furthermore, they agreed that society and gender role socialization has well prepared them and other women to fully engage in the epistemological changes of engineering education. Although sophomores in this study shared that they felt both flattered and hindered by gender, they all reported being prepared to perform in the field of engineering. Not surprisingly, one of the biggest gaps for women shows up in the lack of role models present. White women seemed to be among the largest segment that expressed an inherent advantage in their predominantly male academic setting. Many of them felt that their new found minority status afforded added benefits (like extra care and consideration) and support in this traditionally male dominated profession.

Most students who expressed racial concerns about becoming an engineer shared real tangible issues. Their concerns were mostly about getting a job once they graduated. They took exception with the idea that racism should be a determining factor in an employer's hiring decision. Others who expressed concerns about race/ethnicity either chose to ignore it or opt out of association with their true ethnic identity, to the extent that their skin color permitted. Yet, others shared their feelings of what seemed to be a lost advantage of being a traditional white male in an ever changing society. These students expressed their dissent with systems set up to attract and retain women and minorities in engineering. As the multicultural landscape continues to broaden, racial identity is also a term that must be operationalized and not generalized for discussion among engineering academicians to incorporate in the teaching and learning process.

Further Implications

The data included in this paper represents the experiences, perspectives, and voices of undergraduate engineering students captured during the latter part of their sophomore year. Longitudinal responses captured a year later during the latter part of the students' junior year are forthcoming. The researchers are curiously motivated to analyze year 3 data around this topic. Overall, we would like to examine if maturation of time impacted students' perspectives of diversity and the complexities of their identity in engineering education.

Finally, when studying issues with such paucity as diversity, researchers must consider employing both qualitative and quantitative methods. As stated earlier there were often inconsistencies in what students reported on closed ended questions, quantitatively, and what they reported in their follow-up discussion, qualitatively. For example, when we asked students their opinion on a question they would hesitate, often giggle and provide the interviewer with a scale rating. As the conversation progressed, and presumably their comfort level increased, sophomores shared more candid thoughts about how they really felt about diversity, often in direct conflict with their previous rating. Utilizing a strength-based approach and employing grounded theory, that is using both quantitative and qualitative methods and having no prescribed definitions of the concept of diversity, researchers were able to tease out poignant yet meaningful findings. The absence of either method, while interesting, would have been less robust.

This study contributes important knowledge to the growing body of literature in engineering education and diversity. Unlike many studies cataloging similar information, this research details rare accounts of student experiences in their own voices. These detailed accounts can be instrumental in informing the pedagogical pipeline including educators, researchers, and university administrators about the impact of diversity on the undergraduate engineering experience.

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