"What Really Matters?": A Critical Research Study of the Organizational and Personal Factors Influencing Underrepresented Engineering Students' Retention

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***Abstract* – United States higher education faces pressure to increase its capacity to produce a labor force capable of competing in a global technological economy in the 21st century and beyond. The cohort of "baby-boomers" set to retire by the thousands exacerbates the shortage of employees in STEM (Science, Technology, Engineering and Math) fields. The labor shortage could largely be filled if underrepresented groups (including minorities and women) were utilized in the STEM workforce in parity with their total workforce population.**

In response, the NSF has included a diversity goal included in their research grants to higher education institutions. The Engineering Research Center grants (ERCs) are one way the NSF attempts to support fundamental research and to shift traditional thinking about engineering education. This paper presents findings from three studies focused on a private university's NSF sponsored ERC program's student diversity mission. The first study presents findings from faculty and administrator interviews regarding their understanding of the URM student shortage. The second study explores faculty and staff explanations for the relative increase in female students in the ERC. The third study examines, from the perspective of URM PhD engineering students and key factors influencing their retention.

Index Terms – Retention, Underrepresented Minority Students, Organizational Culture, Organizational Climate.

INTRODUCTION

Advancements in space and defense technology along with the addition of entirely new fields, such as bioengineering and nano-manufacturing, led to tremendous growth in engineering during the latter part of the 20th century [1]. Engineering is the second largest profession in the United States (following teaching), employing nearly one-and-a-half million people [1]. While demands for an increase in engineers has occurred, the number of whites interested in engineering has decreased and the number of underrepresented minority (URM) engineers in the workforce and in undergraduate engineering programs has not increased in parity with their representation in the population [2]. This paper synthesizes the findings from three studies focused on understanding, from faculty, staff and student perspectives, why women and URMs continue to enroll at disproportionately low rates, using one engineering program as the case study.

REVIEW OF THE LITERATURE

I. Trends in diversifying the demographics of engineering programs

The lack of diversity within the engineering profession and workforce is the number two concern articulated in the National Science Foundation's (NSF) 2005 strategic plan [1]. Aside from the issue of quantity, to remain economically competitive, the U.S. workforce must be equipped with the skills and abilities to collaborate with a diverse, international and domestic population of business people [3]. It is postulated that a diverse workforce is one easy way to ensure that.

The decline of students, especially under-represented minorities (African Americans, Hispanics/Latinos, and Native Americans) and women entering STEM (science, technology, engineering, and math) fields in the U.S. is directly related to the looming shortage of qualified researchers and workers in engineering fields. As the U.S. struggles to keep pace both technologically and economically in the 21st century, educational institutions need specific recruitment and retention strategies to expand the STEM pipeline, especially in engineering. Overall, the

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goal must not be simply to increase demographic numbers and representation but rather to insure equitable participation throughout academia and in the workforce.

Undergraduate students. Using one URM population to illustrate the trends, consider that from 1995-2005, the African American college-aged population (18-24 years old) was roughly 14 percent of the total U.S. population yet they comprised only 5.9 percent of undergraduate engineering enrollments [4]. During the same period, the enrollment rate increased considerably for Hispanics and remained steady for Whites, Asians and Native Americans.

African Americans and Asian Americans compose similar percentages of the college-aged citizens (roughly 11percent) each yet Asian Americans, over the last 10 years, have consistently received more than twice as many engineering bachelor's degrees. With the exception of Native Americans, African Americans received the fewest bachelor's degrees in engineering awarded in 2005. Over the last decade, African Americans have also received significantly fewer undergraduate degrees in engineering than have foreign nationals [4].

Gender. In the past thirty years, the number of science, math, and engineering (SME) bachelor's, master's, and doctoral degrees awarded to women has increased by 106%, 150%, and 267%, respectively [1]. Although the gender gap has certainly narrowed in these past decades, women have not yet achieved parity. Currently, women are under-represented among SME degree recipients at all levels, particularly at the graduate level, earning 35% of bachelor's degrees, 26% of master's degrees, and 24% of doctoral degrees [5]. In this case study, compared to the university's overall enrollment, the numbers of female engineering students v. male students in general were 24% and 51% respectively. Female students outnumbered males by a ratio of 6:2 for undergraduates but were slightly smaller at a ratio of 1:3 on the graduate level.

Doctoral students. While there have been important moderate gains in engineering for underrepresented minority and women doctoral students, the continued dearth remains a fundamental concern in academia. With the average attrition rate among all doctoral students at 50% [6], it becomes even more imperative for educational institutions to assess their recruitment and retention efforts of all students, especially underrepresented minority students. Consistent with national findings, for this case study, the School of Engineering's URM doctoral students (N=27) comprise approximately 2.6% of all engineering doctoral students.

If the looming researcher/worker shortage in engineering could be alleviated by increasing the number of URMs coming through undergraduate engineering programs, then we need to understand why so few URMs are currently enrolled in engineering programs. The catalog of one ERC states that it is, "uniquely positioned to accomplish the NSF goal of creating a diverse workforce for the near and distant future." The ERC's stakeholders are interested in determining the extent to which they have progressed towards that goal.

II. Research on attracting and recruiting URM students

Numerous studies have addressed the under-representation of women and other URMs in science, addressing issues such as: Why do young girls seem less interested in science than boys are? What factors discourage women from taking more math and science courses in high school? What factors encourage women to choose to major in SME fields in college? And among them, who persists toward the bachelor's degree?

At the graduate level, for example, several factors have been associated with persistence including the academic climate, faculty interaction, mentoring, financial support, and student self-efficacy [7]. A common theme associated with graduate student persistence is faculty interaction. Unlike undergraduate and Master's engineering students, doctoral students' socialization and educational experience rely heavily on their research relationship with faculty.

The issue with the majority of the research on attracting and retaining students in engineering is that it focuses on the student, and does not also consider organizational culture. Certainly there are student characteristics that contribute to student retention, such as incoming math skills and self-efficacy. However, for many engineering programs, including the one serving as the subject of this study, there are so few women and/or URMs that the issue is how to attract them as a program cannot retain what it does not have in the first place. We suggest that an additional lens, an analysis of organizational factors, needs to be added if we are to understand the dynamics involved in attracting URM students to engineering programs. For the purposes of this study, student persistence and retention refers to a student's decision to continue their educational studies and matriculate to their next academic year. Conversely, attrition occurs when students decide to leave the educational institution.

III. The role of organizational factors in attracting URMs.

An article discussing strategies for recruiting and retaining underrepresented minority doctoral students in Biomedical Engineering, challenges engrained academic beliefs regarding which students are considered more intellectually inclined and suggests that such essentialist thinking must be addressed [8]. The researcher contends, "All graduate training eventually boils down to individual faculty members committing to individual students and vice versa [. . .]. There are various ways to succeed in recruiting and retaining URM doctoral students but key to them all is the creation of real student-faculty relationships, which demonstrate by example that diversity and excellence can and should coexist" [8]. Focusing on the perceived shortcomings of the students, or "deficit thinking" blinds faculty to the role of the academic climate in reifying this disparity.

A study advancing specific strategies for educational institutions that seek to recruit, retain and graduate URM doctoral students identified organizational traits and characteristics of successful institutions [9]. Some of the findings included establishing an early pipeline and exposure to the field, strong university support, focused recruitment and admissions policies, a welcoming organizational and academic climate, dedicated professors, role models and mentoring, and community building.

In a study providing compelling support that faculty interaction and representation are integral to graduate student retention and success, it was found that the most significant predictor of the enrollment, retention, and matriculation of African American graduate students is the presence of African American faculty [10]. This conclusion suggests that there is interrelatedness between the representation of faculty and enrollment of students from underrepresented groups.

What the next three studies contribute, the subject of this paper, is a deeper understanding of the shortage from the perspective of faculty, administrators and doctoral students. Knowing more about how they define the problem, where they place responsibility, and where they see evidence of success can help us more effectively address the shortage.

THE RESEARCH PLAN

The purpose of these studies was to examine factors influencing the recruitment and retention of undergraduate and graduate underrepresented minority and female students to a School of Engineering, and more specifically an Engineering Research Center. The primary units of observation were a purposeful sample of faculty, administrators, staff, and current and former URM and female engineering students. To aid in triangulation of the data, we also analyzed organizational artifacts including marketing and BMES publications.

The research questions for the faculty and staff were:

- How do they understand the current enrollment (or lack thereof) of women and URMs in their undergraduate and graduate engineering program? To what do they attribute the low numbers?
- What value does increasing the presence of URMs and women hold for them?
- Where do they place responsibility for increasing the diversity of the programs?
- What successful strategies do they identify? What do they suggest for improvement?

For the current and past PhD students, the questions were:

- What do URM PhD Engineering students identify as the key factors influencing their retention?
- To what extent do their experiences differ across specializations and year within the program?
- For those involved in the ERC, what role if any, does it play in their decision to stay or leave the program?

METHOD

The studies looked for respondents' "theories in practice" by using in-depth interviews employing a "*naturalistic* inquiry research design" [11]. Naturalistic inquiry is a qualitative method of investigating real-world phenomena in its natural setting without research controls or manipulations [11]. The intention is to bring to bear a sense of each person's voice through open-ended questions with the goal of having the participant reconstruct his or her experience within the topic under study [12]. The personal perspectives provide a context for the policies, policy implementation and practices that create the culture of the ERC.

III. Site for the study

The case for this study was a single department within a school of engineering at a large, private research university. The department, one of seven, runs an NSF-funded ERC. In the University's undergraduate engineering school, Hispanics represent 11% but 5% of the ERC. Blacks represent 3.8% but 2% of ERC. American Indians represent .45% but 0% in ERC. All the above minorities are also underrepresented in the department that houses the ERC. With the exception of Whites and Asians, all ethnic minorities are under-represented at the University, although the numbers are higher than many other similar institutions.

There are two undergraduate programs aimed at increasing diversity at the BMES ERC, the Research Experiences for Undergraduates (REU) and the Tribal Colleges and Universities Program (TCUP). REU, the 8-week summer program is designed to increase the diversity of the scientific and engineering workforce by including all members of society, regardless of race, ethnicity, or gender, in all aspects of the centers' activities. Students will receive: (1) $3,200 stipend for the 8-week program, (2) paid housing in University dorms, (3) travel support, (4) personal mentoring by the University's researchers and graduate students, and (5) research experience. Similarly, TCUP is a 2-week summer program.

IV. Data collection

All 11 faculty and staff affiliated with the ERC were invited to participate in an interview. At the time of this paper, 7 had responded, resulting in a 64% participation rate. The interviews were semi-structured, and used a common interview guide [11] One hour semi-structured interviews were conducted with the 3 URM doctoral students representing different specializations. The specific interview protocol asked what factors, including academic preparation, academic climate, faculty interaction, mentoring, and participation in ERC classes contributed to their persistence. Each of the interviews were transcribed and carefully analyzed to accurately convey the participants' thoughts. We then analyzed all the data from the interviews and report it below by theme.

FINDINGS

V. Increasing undergraduate diversity

Faculty, administrators and staff offered multiple explanations for the under-representation of "minorities" in the ERC program yet there was consensus regarding overall satisfaction with the efforts of the all of the stakeholders to increase females and URMs in the ERC, given the constraints under which they were operating.

Perhaps the simplest way to understand participants' responses, described below, is from the perspective of "locus of control." Locus of control refers to where an individual situates responsibility for taking action [13]. Those with an internal locus of control see themselves as responsible for the

things happening to them; those with an external locus of control place responsibility on people and events outside of themselves. Responses from faculty and staff generally revealed an external locus of control with respect to increasing the diversity of the ERC student population. For example, the most frequently cited challenge for implementing a diversity mission was the leak in the pipeline. The point is well taken that there is a very limited pool from which to draw but the question is, of those in the pool, however small, why are they going to other institutions or programs and not to this one? There appeared to be consensus that, "We are a very great University" that has similar, if not better academic and social support for students but it is difficult to compete with universities considered to be larger and more prestigious. Not having enough financial aid to compete with these institutions was seen as an issue.

They also pointed to the lack of interest in, or lack of knowledge about engineering and biomedical engineering on the part of URM high school students; the unit's lack of control over the University's centralized undergraduate admissions process; and the University's and ERC'S inability to compete with other top research institutions for a limited talent pool. These explanations place responsibility outside the role of the individual faculty or staff member, and even outside the academic unit.

The National Science Foundation Diversity requires an education and diversity component in each ERC grant. While the level of priority and commitment by faculty and staff to the recruitment of URMs varied, the NSF's diversity imperative was consistently alluded to as the primary motivation to focus on the URMs. One participant considered the NSF diversity imperative to be "a laudable goal" as it attempts to make researchers, "responsible, not just for the research but for the next generation of researchers." A faculty member said their motivation stems from a "combination of knowing it is a priority with the NSF and feeling like it's the right thing to do." "The right thing to do," according to that participant, is based on utility rather than a moral imperative: Engineering and science is damaged if the pool of applicants is artificially constrained."

A few responses suggested that some faculty are beginning to see their own role in increasing student diversity. For example, some faculty and staff discussed: lackluster motivation on the part of the University and the ERC program stakeholders to recruit and retain URMs; and ERC stakeholders' lack of knowledge about recruitment and retention strategies. Several others, when asked about ways to increase the presence of women, specifically, noted the role of faculty in reinforcing women's self-efficacy. "What keeps women in engineering is that no one ever tells them that they can't do it. No one ever says that you're not as good as your male counterparts. If it's in their minds that they are just as good as anyone else in accomplishing their career and academic goals, they are more likely to persist."

The literature suggests that here is where true gains can begin – when the department acknowledges its responsibility in increasing diversity, it will begin to take effective action. Indeed, one faculty member postulated that retention of URMs has not been strategized in a culturally sensitive manner, particularly relative to connecting with the URMs' sense of responsibility to their community. This participant was the only one who alluded to the needs of the URMs from the reference point of the URMs. The participant spoke of an organizational culture at the ERC that insists on conformity with the status quo of a scientific persona and community, and does not consider the uniqueness of students and their backgrounds.

VI.URM Graduate Student Recruitment and Retention

During separate interviews, three current underrepresented minority doctoral students shared their thoughts on diversity in the engineering program. The most recurring themes included: program culture and the role of mentoring in navigating that culture; self-efficacy, academic preparation, academic specialization, cultural isolation, and diversity among students, faculty, and staff.

Department culture and the role of faculty interaction, mentoring, and recruitment. Participants noted that the complex and unique culture of a doctoral program did not necessarily promote community. Different from undergraduate and Master's students, doctoral students' academic experience relies heavily on their research with a faculty member. Consistent with earlier research findings, faculty support and interaction was essential at the doctoral level. They understood the simple, yet profound reality that the increase of URM students pursuing a PhD has a direct correlation to the pool of qualified faculty in the classroom. This cyclical interdependence also impacts future recruitment of prospective students as many will seek an educational institution that has some representation of faculty similar to themselves.

While each of the students agreed that the overall academic climate was generally welcoming, they each expressed concern regarding the low number of URM students in the program especially the doctoral program. The students also discussed the need for mentoring and support more formally than the informal channels that are often limited.

Student initiative. The desire to have a diverse community prompted students to establish a minority graduate association to address some of the concerns previously mentioned and to institutionalize efforts designed to increase the number of URM doctoral.

Support external to the university. The most salient factors consistently identified as key retention factors were strong familial support and personal determination. Each of the students noted their genuine interest in engineering as the impetus for their continuation.

Uncertainty about financial support is a deterrent. Funding was stated as a concern due to the need to apply every two years versus a secured fellowship for the entire program.

RECOMMENDATIONS

The Engineering Workforce Task force reported that the educational culture of engineering is "at odds with the value systems of most minorities," that new administrative structures may be needed" to enhance multidisciplinary

approaches to learning and research, and a "new kind of faculty may be needed to understand innovation in industry" [2]. Essentially, the Task force has hinted at the kind of transformation that engineering programs have not historically prepared faculty and program leaders to undertake. The following directives address strategies from the pipeline to the overall organizational culture.

- *Admissions*: Partner with the admissions office in a more proactive way to impress upon them the high stakes involved. Survey students who declined admission to determine why they chose another institution.

- *Undergraduate Diversity Programs*: While the programs may provide positive benefits for the populations served by them, they have not increased the enrollment at the University/ERC or any URMs. The REU/TCUP programs must explore ways of providing admissions assistance for students to explore their transfer options.

- *Academic Community:* Create an academic community that is student-centered, to the extent that stakeholders understand and support the unique backgrounds/challenges faced by students relative to their demographics. Reinforce how the coursework and profession connects to an ethos of service to community that is so important to URMs and females.

- *Doctoral Recruitment and Admissions Process*: To increase the number of URM doctoral students, this School of Engineering should identify and implement strategic initiatives designed to broaden traditional recruitment processes that generally rely primarily on quantitative measures to determine admittance. A more holistic approach that encompasses a variety of strategies including outreach to Historically Black Colleges and Universities, and Traditionally Hispanic Serving Institutions would increase the pool of qualified applicants. The School of Engineering must challenge historical "deficit" discourse and resist the tendency to bemoan the notion of a "non-existent" pipeline. While in fact the URM student pipeline may be limited in size, it is not limited in talent.

- *Organizational Culture and Institutional Support*: In that increasing the number of URM students and faculty will enhance the overall academic culture and experience, this School of Engineering must continually assess its organizational mission and stance as it relates to diversity. There must be specific directives and practices valuing diversity along with complete institutional buy-in from all constituents. The consistent message regarding the School's commitment to diversity must be exemplified in disparate ways including its artifacts, policies, and programs. To convey institutional support for the increase of URM doctoral students and faculty, the School must provide consistent and substantial financial assistance as well as support organizations such as a minority graduate association.

- *Faculty Perceptions and Interaction*: As noted earlier, faculty perceptions and interaction are the most integral factors affecting graduate student retention. A fundamental commitment to view URM doctoral students as having the intellectual acumen to conduct rigorous and significant research is essential for organizational success.

NEXT RESEARCH STEPS

To further understand the dearth in the number of URM and female students in engineering, additional studies could examine the admissions process of elite institutions. This could provide insight on what factors are more highly valued in the overall student evaluation process.

Additionally, a longitudinal study chronicling an URM doctoral student from the application process through graduation could create a lens by which the various factors influencing their retention can be analyzed.

CONCLUSIONS

Essentially the BMES ERC is doing many things right:, they have the diversity center, the REU and TCUP, and a pipeline program for high school students at a local science magnet school (the subject of a collaborative study in this series) and they are focusing on new solutions like the Engineering for Health Academy.

In order to achieve its diversity mission, the stakeholders of the BMES ERC may benefit from expanded dialogue about the needs of the URM and females students they hope to attract and retain. The literature suggests that as the unit takes more responsibility for attracting and retaining URMs, it will see gains. We saw evidence of some efforts in that area, and while more is needed, the lack of effort was not due to a disregard for URMs, in fact, some participants in the interview setting asked for assistance in thinking through what they could be doing differently to attract a more diverse student body. We found this to be very encouraging.

To their credit, one major asset of the ERC is that they have the courage to talk openly about where they see their shortcomings, and to accept feedback from the research team. This is perhaps the most powerful finding of all.

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