# AC 2008-2297: FACTORS SUPPORTING PERSISTENCE OF FEMALES IN UNDERGRADUATE ENGINEERING STUDIES: INSIGHTS GAINED THROUGH A QUALITATIVE ANALYSIS OF CONSISTENTLY PERFORMING PROGRAMS

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# Factors Supporting Female Persistence in Undergraduate Engineering Studies: Insights Gained Through a Qualitative Analysis of Consistently Performing Programs


## Abstract

As part of our overall research into the issues of retention/persistence of female undergraduate engineering students, we identified and investigated programs that consistently conferred at least 30%, on average, of their baccalaureate degrees to females over a five year period. A qualitative analysis of six of these programs, all located in Historically Black Colleges and Universities (HBCUs), reveals five factors that encourage female persistence. The HBCUs were selected for this analysis due to the relative homogeneity of their student populations, which helps to reduce the impact of confounding factors on the analysis. In addition, they have managed to be successful with limited resources; the identified factors reflect institutional will and mission rather than economics and therefore are more universally adoptable. The results, obtained primarily through document review, are verified via triangulation with other data sources including interviews and representative sources from the literature. The success of these six programs in enabling female undergraduates to persist to graduation is further proof of the importance of climate, cultural, and environmental factors on the ability of retention/persistence strategies for female undergraduates in engineering to be successful. We recognize that these results are not unknown; however, they provide further evidence that a paradigm shift in the structure and delivery of undergraduate engineering studies is necessary to increase the overall percentage of female undergraduates receiving degrees in engineering.


## Introduction

A central question in the research on the persistence of female undergraduates in engineering is "which factors contribute to the success of members of this population segment persisting to graduation?" Much research has been devoted to the identification of academic and social factors contributing to persistence,[i] but none, as far as can be determined, addresses the question using the strategy upon which the research presented in this paper is based: a review of consistently high-performing programs. We therefore decided to perform a qualitative analysis of engineering programs which have conferred at least 30%, on average, of their baccalaureate degrees to females from Academic Year (AY) 2001 (Class of 2002) to 2005 (Class of 2006) to identify core, common factors which support persistence of female undergraduates in engineering studies. The floor of 30% represents a level of achievement above the national average of approximately 20% of undergraduate engineering degrees conferred to females (as of AY 2005, 19.3%.[6]). The data are from the American Society for Engineering Education's (ASEE) series *Profiles of Engineering and Engineering Technology Colleges*.[1-5]

The observation that overall retention rate of female undergraduates has been relatively flat or rising slowly for the past decade despite concerted, dedicated efforts at many institutions motivates this research and leads to the conclusion, reinforced by representative entries in the literature,[7-9] that there are entrenched cultural barriers, both institutional and personal, to retention/persistence of female undergraduates in engineering to graduation. This research addresses factors which may ameliorate institutional barriers for these students. The

identification of these supportive factors is the first step in changing institutional characteristics that aren't.

"Barriers" are defined as manifestations of cultural elements, such as attitudes and policies, which undermine the basic factors affecting student persistence/retention in undergraduate engineering studies: self confidence,[9, 10, 11] attitudes towards engineering,[9, 12] quality of instruction,[8, 13] and the quality of the college experience.[12] *Persistence* is a student-determined behavior; *retention* is a program-based activity.

We begin with an overview of the methodology used in this analysis, the research/inquiry paradigms informing the methodology, and the theoretical frame guiding the analysis. Next, the qualifying programs are identified and the selection criteria for the six programs used in the analysis is further described. "Thumbnail" sketches of the selected programs – brief overviews of the institutions' histories and relevant enrollment figures – are provided in way of introduction.[ii] After a discussion of the factors identified through the described analytical process, we end with conclusions and possible directions for future work in this area.

**Methodology**

The methodology used in this analysis relies heavily on document review, a widely accepted and validated qualitative analysis technique.[14] The paradigm guiding the methodology – our analytic lens – is a mixture of the constructivism/interpretive and critical theory inquiry paradigms, since these paradigms support inductive reasoning and qualitative research.[15, 16] The collective positionality of the researchers are ones supporting and championing diversity in all sectors of the "engineering society," recognizing that a more inclusive population leads to more inclusive and representative solutions to the problems and issues addressed by the "society."

The initial review of high-performing programs, performed using the institutions' web sites,[17] helped develop a set of emergent guidelines to use in focusing the subsequent detailed qualitative review of the selected programs' structure, staffing, and offerings. The guidelines are grounded in the following theoretical frame developed from the literature: that persistence is more likely when female students receive the support to which they're accustomed from high school from key mentors who provide examples and strategies for survival in a male-dominated profession; when the peer group is well represented, lessening the chance of isolation; and when programs have features that fit well with preferred learning environments for female undergraduates, such as interdisciplinary studies with a stress on the inclusion of liberal arts courses, flexibility, low student-faculty ratio, no pigeon-holing or stereotyping by faculty and fellow students, project and team-based learning, emphasis on design projects (including service learning), and support of innovation and entrepreneurship in both faculty and students.[7, 8, 10, 18-22] We are interested, therefore, in data on program size, student and faculty diversity, and statements and services revealing the extent to which student persistence is supported, for example. The result of our research is the identification of five factors that foster the type of community we believe essential to the persistence of female undergraduate engineering students. The factors are verified through triangulation with other data sources including interviews and representative sources from the relevant literature. Triangulation is an accepted method of confirming findings in qualitative research by noting convergence with findings in independent sources studying the same phenomenon.[23]

**The Programs**

The consistently performing programs with respect to the percentage of baccalaureate degrees in engineering awarded to females fall into one of two categories: minority serving institutions – Historically Black Colleges and Universities (HBCUs) and an Hispanic Serving Institution (HSI) – and elite private universities. The HBCUs, the majority of which are the official 1890 Morrill Land-Grant institution for its state, are: Alabama A&M University (AAMU), Normal, AL; Morgan State University (MSU), Baltimore, MD; North Carolina A&T University (NC A&T), Greensboro, NC; Prairie View A&M University (PV A&M), Prairie View, TX; Tennessee State University (TSU), Nashville, TN; and Tuskegee University, Tuskegee, AL. Southern University and A&M College, Baton Rouge, LA, met the criterion for AY 2001 – 2003. The HSI is the University of Puerto Rico-Mayaguëz (UPR-M). The private universities include Brown University, Providence, RI; California Institute of Technology, Pasadena, CA; Lafayette College, Easton, PA; Massachusetts Institute of Technology, Cambridge, MA; Mercer University, Macon, GA; Northwestern University, Chicago, IL; Princeton University, Princeton, NJ; Southern Methodist University, Dallas, TX; Tufts University, Medford, MA; William Marsh Rice University, Houston, TX; and Yale University, New Haven, CT. We also include the programs at Franklin W. Olin College of Engineering, Needham, MA, and Smith College, Northampton, MA in the initial review because of these institutions' commitment to educating female undergraduates and their use of innovative educational techniques in designing and implementing their programs.

These programs have several cultural elements in common, such as (relatively) small size and committed institutional support. We choose to focus our analysis on HBCUs since they have been able to graduate female undergraduates at roughly the same rates with fewer resources, allowing for identification of factors that are both successful and achievable. Also, the institutions' student populations are fairly homogeneous, which helps eliminate potentially confounding factors from the analysis. While relative homogeneity of the student population is also a characteristic of UPR-M, the school is a single data point.

The degree percentages for the selected HBCUs are given in Table 1.

Table 1. HBCU Leaders in the Percentage of BS Degrees in Engineering Conferred to Females, in Alpha Order, AY 2001 – 2005[1-5]

| | Academic Year | | | | |
|---|---|---|---|---|---|
| | 2001 | 2002 | 2003 | 2004 | 2005 |
| Alabama A&M | 41.2 | 41.2 | 41.2 | 36.1 | 36.1 |
| Morgan State | 35.4 | 35.4 | 32.2 | 36.7 | 28.4 |
| North Carolina A&T | 39.4 | 35 | 40.8 | 36.6 | 23.2 |
| Prairie View A&M | 40.8 | 32.5 | 32.7 | 32.9 | n/a |
| Tennessee State | 49.5 | 41.6 | 37 | 38.6 | 45.5 |
| Tuskegee | 46.7 | n/a | 45.3 | 34.6 | 36 |

We acknowledge the inherent drawback in using percentages, a relative measure rather than an absolute one. It can be difficult to interpret the results correctly without some notion of magnitude. Since AY 2002, however, programs must have granted a minimum of 50 degrees in

order to qualify for inclusion in Gibbons' studies. The number of degrees granted by the selected HBCUs to African Americans (the institutions' majority population) over the same time period, as reported in Table 2, helps to size the discussion.

Table 2. Number of B.S. Engineering Degrees Awarded to African Americans at Institutions Listed in Table 2, AY 2001 - 2005[1 - 5]

| | Academic Year | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2001 | 2002 | 2003 | 2004 | 2005 | Mean | St Dev | Median |
| Alabama A&M | 60 | 60 | 60 | 70 | 70 | 64 | 5.48 | 60 |
| Morgan State | 93 | 93 | 62 | 63 | 51 | 72.4 | 19.39 | 63 |
| North Carolina A&T | 222 | 207 | 149 | 206 | 138 | 184.4 | 38.07 | 206 |
| Prairie View A&M | 66 | 74 | 46 | 80 | 60 | 65.2 | 13.16 | 66 |
| Tennessee State | 85 | 82 | 109 | 89 | 60 | 85 | 17.51 | 85 |
| Tuskegee | 70 | 46 | 63 | 50 | 61 | 58 | 9.82 | 61 |

HBCUs have a common ethos, due primarily to their history. Among the shared values are a philosophy of inclusiveness, a dedication to the development and nurture of the whole person, and a commitment on the part of the whole institution to student success and empowerment.[24-29] The schools also take the point of view that the institution adapts to the student, not the other way around.[27]

**Institutional "Thumbnail" Sketches**

*AAMU*. Founded in 1875 as the Huntsville Normal School, AAMU earned land-grant status in 1891, moved to Normal at that point to provide room for the expansion of its industrial trades and agricultural programs, and adopted its current name in 1969.[30] Its enrollment as of Fall 2007 is 4,716 undergraduates and 990 graduate students for a total enrollment of 5,706.[31] An undated document reports that there are 1,011 undergraduates enrolled in the College of Engineering and Technology.[32]

*MSU*. In 1867, MSU was founded as a private institution, the Centenary Biblical Institute, whose mission was to train ministers, by the Baltimore Conference of the Methodist Episcopal Church. It became Morgan College in 1890 in honor of the Reverend Lyttleton Morgan, the first chair of the Board of Trustees and major benefactor. The 1917 move to its current site was funded by a grant from Andrew Carnegie. The State of Maryland bought the college in 1939, and designated the school as a university in 1975.[33] The full-time undergraduate enrollment in Fall 2006 was 5,334; the full-time graduate enrollment was 396.[34] The full-time undergraduate enrollment in the College of Engineering that year was 678.[35]

*NC A&T*. NC A&T began in 1891 as the Agricultural and Mechanical College for Negroes in Raleigh; the school moved to Greensboro in 1893 and adopted its current name in 1967, when the state designated it as a regional university.[36] Its enrollment as of Fall 2007, is 9,048 undergraduates and 1,450 graduate students for a total enrollment of 10,498.[37] The College of Engineering reported an enrollment of 1,533 undergraduates, 207 master's students, and 71 doctoral students in Fall of 2006.[38]

*PV A&M*. PV A&M is Texas' second oldest public post-secondary institution. It was founded in 1876 as a normal school named the Agricultural and Mechanical College of Texas. It earned land-grant status in 1890, and assumed its current name in 1973.[39] It achieved its largest enrollment, 8,382 students, in Fall 2007.[40] The College of Engineering granted 134 undergraduate and 15 master's degrees in AY 2005.[41]

*TSU*. The Agricultural and Industrial State Normal School was established by state law in 1909, enrolled its first class in 1912, gained land-grant status in 1958, and became TSU in 1968.[42] In Fall 2005, 7,112 undergraduates and 1,926 graduates were enrolled at the university.[43]

*Tuskegee*. Founded as a normal school in 1881 with the legendary Dr. Booker T. Washington as its first instructor and then principal and president, Tuskegee became an independent (private) institution in 1892 and achieved university status in 1985.[44] Its Frequently Asked Questions site reports an (undated) enrollment of approximately 3,000 students and a faculty-student ratio of 13:1.[45]

**Results**

To restate our thesis, institutional climate, culture, and environment[iii] have a strong influence on a program's abilities to recruit, retain, and graduate female students successfully – and there is a certain set of climate, cultural, and environmental factors that promote persistence by female undergraduate engineering students. We believe that the following factors, identified through detailed qualitative analyses of the information available on the schools' websites and verified by noting convergence with the findings of independent sources studying and reporting on persistence of female undergraduates in engineering,[46-48, I1-I4] foster the type of community that is essential to the persistence of female undergraduate engineering students:

1. **Size matters**. The lower the student-faculty ratio, the more likely female students are to receive the nurturing through mentoring and individual attention – nurturing they're accustomed to from high school – needed for significant degrees of persistence.[8] Also, it's easier to develop a "critical mass" of female students in a smaller program than it is in larger ones; again, presence of peers is cited in the literature as one factor that support persistence.[7, 8, 10, 18] A smaller program size means that the program is more likely to have the agility, flexibility, or desire to adopt the student-centered practices that characterize the HBCUs. Finally, and obviously, it's easier to increase percentages in a smaller program. Recruiting, retaining, and graduating ten additional female students results in a larger impact in a program with an enrollment numbering in the hundreds than in one enrolling thousands.

2. ***Everyone* is committed to student success**. And we do mean **everyone** – it really does "take a village"! Support programs and organizations such as women's centers and the Society of Women Engineers are absolutely essential to the successful development of female undergraduates, but the programs and organizations may not be as successful as possible without full and uncompromising support from administration, staff, and faculty. A strong "family" atmosphere is less likely to arise and persist if key elements of the community are not engaged either through choice or habit. It's harder for a student to "fall through the cracks" with intense mentoring and monitoring – which is easier, admittedly, in a small program. These institutions have consciously cultivated a "community of caring," in the words of Mrs. Velma Moore, Office of the Dean of the College of Engineering, Architecture, and Physical Sciences, Tuskegee University.

3. **Teaching is valued in the institutional culture**. The institutional identities for these programs are centered in the academic and social development of their students. As the institutions matured, value for teaching did not diminish as research programs developed. Research and teaching are not mutually exclusive pursuits; both are fully supported and valued in an optimal academic setting.

4. **Public presence of female faculty**. All faculty, including adjuncts, are listed and, for the most part, pictured on departmental web sites. Prospective and current female undergraduates can thus receive assurance that female mentors will be available to work with them. Table 3 lists the percentage of female faculty at the six programs featured in this research.[17] The data are from qualitative and quantitative reviews of department web sites. If no pictures are available, gender identification is based on faculty first names. These figures, for the most part, compare favorably with the national overall percentage of 11.3% of female faculty in tenured and tenure-track positions.[5] Female faculty are especially well represented in computer science, comprising, on average, 23% of the faculty.[17] Nationally, 12.6% of the faculty of computer science departments in engineering schools are female.[5]

Table 3. Engineering Faculty Data for Programs in the Detailed Study

| | Total Faculty | # Women | % |
|---|---|---|---|
| Alabama A&M | 32 | 3 | 9.4% |
| North Carolina A&T | 90 | 9 | 10.0% |
| Morgan State | 38 | 4 | 10.5% |
| Prairie View A&M | 38 | 4 | 10.5% |
| Tennessee State | 42 | 8 | 19.0% |
| Tuskegee | 44 | 3 | 6.8% |

5. **Affordable educational experience**. Relatively low tuition supports the matriculation and persistence of first generation students and / or students from low-income households.

Initial research results indicate that these factors enable success in retaining female undergraduate engineering students in all disciplines, not just in the disciplines that could be characterized as "female friendly," based on the number of degrees granted to female undergraduates, such as environmental and biomedical engineering. This outcome is important, given that females graduates are grossly underrepresented in the disciplines of electrical and computer engineering, mechanical engineering, and computer science: disciplines in which the great majority of undergraduate degrees are awarded.[5] These factors also go a long way to dispelling or dismissing altogether perceptions that engineering programs and personnel are impersonal, inaccessible, inflexible, and inhospitable towards females: perceptions that form very real barriers to retention/persistence by discouraging or actively preventing females from engaging in engineering studies.

**Conclusions and Directions for Future Work**

Many large-scale engineering programs at research-oriented institutions provide small-scale experiences to support persistence of female undergraduates.[49-52] However, if climate, culture, and environmental issues inimical to female retention/persistence are not remedied, these programs may not achieve their goals as well as envisaged. The data suggest that small-scale, student-oriented initiatives must occur across the board in order to be optimally effective. That is, concurrent reform needs to take place in the curriculum, faculty, administration, degree requirements, course schedules, plans of study, instructional techniques, access to research opportunities and mentoring/advising relationships in order to neutralize barriers to retention/persistence most effectively. In other words, the Victorian, industrial model of technical education in which students are processed like so many widgets is no longer viable and must be reassessed. The persistence of this out-of-date model is a testament to, among other considerations, institutional inertia; no other industry would tolerate overall "wastage" (not retained to graduation) of roughly half the "product."[53]

Calls for institutional reform are not new in the engineering education community; see, for example, the National Science Foundation's ADVANCE program. Our research is merely additional confirmation that reform is needed if we are to reach the goal of retaining female undergraduates in engineering to graduation.

In addition, a change to the format of the section of "The Year in Numbers" in which percents of degrees earned by students from underrepresented populations in engineering may be indicated. If programs are grouped by size, much like the institutions' athletic teams in various NCAA Divisions, then "apples" may be compared to "apples," and the achievement of a broad range of programs recognized. It would also be helpful to have the raw data upon which the percentages are based reported, along with the percent change from the previous year. Reporting four-year, five-year, and six-year graduation rates would also help place the percentage data into perspective.

Finally, it may be helpful for students and programs alike to investigate the fit between personal and institutional culture as part of the recruitment process. One of our current working theses is that the degree of fit between personal and institutional character is a major determinant in the persistence of female undergraduate engineering students. Support for this theory is found in the literature[8, 14] as well as anecdotal evidence from accounts of students who transferred out of

engineering[15]. We are using this theory to guide the development of a "culture index" as well as a simple device to facilitate analysis and comparisons of institutional cultures.

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| HBCUs Upon Which This Research is Based | Other High-Performing Institutions Reviewed | | |
|---|---|---|---|
| www.aamu.edu | www.brown.edu | www.olin.edu | www.uprm.edu |
| www.morgan.edu | www.caltech.edu | www.princeton.edu | www.yale.edu |
| www.ncat.edu | www.lafayette.edu | www.rice.edu | |
| www.pvamu.edu | www2.mercer.edu | www.smith.edu | |
| www.tnstate.edu | www.mit.edu | www.smu.edu | |
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*Interviews*

I-1. Dr. Derrek B. Dunn, Professor and Chairperson, and Ms. Angela Lemons, Instructor, Department of Electronics, Computer, and Information Technology, North Carolina A&T State University, June 24, 2007, at the 114th ASEE Conference and Exposition, Honolulu, Hawai'i.
I-2. Akilah L. Hugine, Ph.D. student, Department of Systems and Information Engineering, University of Virginia (BSEE, North Carolina A&T State University; MSEE, Virginia Polytechnic Institute and State University), various dates and venues.
I-3. Mrs. Velma Moore, Office of the Dean of the College of Engineering, Architecture, and Physical Sciences, Tuskegee University, June 26, 2007, at the 114th ASEE Conference and Exposition, Honolulu, Hawai'i (and daughter, who spoke on the difference between Tuskegee and the University of Alabama).
I-4. Students in CU101, University Survival Skills Course (instructor, Sue Lasser), Clemson University, 29 October 2007.

[i] The references listed at the end of this paper is a representative selection.
[ii] The amount of information available through online fact books varied greatly from institution to institution; therefore, the sketches do not follow a standard format with respect to the reporting of enrollment figures.
[iii] Climate: intangible sense that people have about whether they belong, trust, and are involved; culture: beliefs, values, and assumptions people make about each other; and environment: curriculum; instructional practices, strategies, and methods; assessment decisions; administration, instructional staff, and students.[24] (p. 64)