



How Students Choose their Engineering Major: Effects of Gender and Race or Ethnicity

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Introduction

The lack of diversity and inclusiveness in the engineering workforce and engineering college programs has long been well documented and studied in the engineering education community¹. It is not a new problem, and beyond the very real personal and human toll this circumstance takes on individual members of those underrepresented groups (both Women and minorities), collectively society suffers by losing out on a vast pool of talent that could lead to better engineered solutions. For example, the new Apple Health app tracks a person's weight, allergies, medications, even the steps they take each day... but not a woman's period, which is a glaring omission when you consider that the 1st question a woman gets each time she sees a doctor, for at least 30 to 40 years, is usually "When was the date of your last period?"

While the picture is bleak for women, whose representation in U.S. engineering programs has been around 18% for at least the past decade, it is even bleaker for African-American students, whose representation is in the single digits: around 6.5% at our institution, and an average of 4% nationally.

Research on URM students has generally focused on students who leave engineering and what caused their departure. For example, Marra et al.² shows students of both genders tend to drop out of engineering primarily for two reasons: 1) the curriculum is too challenging and the quality of teaching too poor, and 2) students don't believe they belong. Ohland et al.^{3,4} present an extensive analysis of retention measures and student educational experiences at the undergraduate level, and uses a semester-level measure of retention. His group used the large, multi-institution dataset MIDFIELD and found that in general, paths of persistence are nonlinear, gendered and racialized, so one should use multiple measures to assess retention when analyzing diverse populations of engineering students.

Looking specifically at women, studies have shown that they can suffer from a lack of peer support, role models, and adequate academic preparation. All these problems can cause these students to transfer out of engineering⁵⁻⁸. Women also tend to report that teaching styles, subject matter relevance, and the culture of the discipline affect their retention and eventual completion of the degree⁹ more so than for men. Additionally women report that tutoring services are important to their academic success and ultimately, their retention – more so than for men, even after considering academic preparation and race or ethnicity. Studies show that unlike men, women studying engineering tend to be better retained if the institution offers support such as strong ties to faculty and other students, tutoring, availability of numerous student clubs, and living/learning communities^{10,11,12}.

In the case of African-American engineering students, their numbers are so low that nearly all studies mix together both fields of study (across the STEM – Science, Technology, Engineering

and Mathematics – curriculum) and the institutions (from HBCUs to community colleges to 4-year non-selective colleges to Research 1 institutions), rendering the results much more difficult to apply to one’s specific university. Malcolm et. al.^{13, 14} looked at African-American women in STEM fields, almost 40 years after the seminal “The Double Bind” report, and unfortunately, their work shows that while there has been some progress at attracting such students into STEM, the progress has been and remains excruciatingly slow. Espinosa¹⁵ and Reyes¹⁶ propose to speak of pathways rather than the more common concept of “pipeline” to explain the paucity of Black females in STEM fields.

The above referenced studies have provided a stark and disturbing picture of the personal and institutional reasons for leaving engineering. In our work, we are interested in approaching this national problem of engineering diversity from a different perspective. We are interested in the African-American students and women who do persist and succeed in learning environments that are demanding and perhaps even hostile. We want to understand the pathways, the personal strategies and mechanisms that these students have developed and use to find and create a space for success. Our research strategy focuses on individual and institutional **assets** rather than individual or institutional deficits (inadequate preparation, poor teaching) which are foregrounded in previous work. We are fortunate that our institution, the Georgia Institute of Technology (“GT”), is the largest producer of minority engineers, women and African American, in the country, and their numbers are large enough for us to probe for and identify patterns and trends. Thus we are seeking answers to the following overall question: What personal attributes, strategies, and resources make it possible for a minority student to persist and succeed in a highly competitive, research-focused, majority institution?

We would like to emphasize this study is in its preliminary stages, and as such is far from complete. Our interviews are only a start on answering the many questions associated with increasing diversity. As we continue to interview more students, we hope to derive a set of commonalities that we can then test on the larger student body using a simple survey.

Institution Characteristics

GT is a mid-size, STEM-focused institution in the Southeastern part of the United States. It is located in an urban area and has a Research 1 Carnegie classification. It offers eleven engineering majors (aerospace, biomedical, civil, chemical and biomolecular, computer, environmental, electrical, mechanical, industrial, nuclear and materials), spread in eight schools under the umbrella of the College of Engineering (“COE”), and is among the top producers of female and minority engineers. Its College of Engineering represents 60 to 70% of GT’s student body; as well as faculty and staff population. In the two tables below, we present demographic data on the students in each engineering major and rates of graduation. All data presented in the following tables can be found on the GT Institutional Research and Planning website, www.irp.gatech.edu.

Major	Gender	American Indian or Alaskan Native	Asian	Black or African American	Hispanic or Latino	Native Hawaiian or Other Pacific Islander	Two or More Races	Unknown	White	Total
AE	M		147	50	69	0	22	13	433	736
	F	0	29	6	12	0	7	0	77	131
Total			176	56	81	0	29	13	510	867
BME	M	0	233	32	51	0	23	7	289	635
	F	0	205	38	33	0	31	10	324	641
Total		0	438	70	84	0	54	17	613	1,276
ChBE	M	0	168	31	45		29	8	314	596
	F	0	93	28	27	0	9		186	347
Total		0	261	59	72		38	12	500	943
Civil E	M		67	25	37		7		192	331
	F	0	22	23	22	0	8		81	157
Total			89	48	59		15		273	488
CompE	M	0	166	50	30		13	6	201	468
	F	0	30	12	6	0	6		21	77
Total		0	196	62	36		19	8	222	545
EE	M	0	265	64	48	0	26	11	373	787
	F	0	54	18	6	0	7		54	141
Total		0	319	82	54	0	33	13	427	928
Environmental E	M	0	18			0		0	39	66
	F	0	16	13		0		0	83	117
Total		0	34	16	6	0	5	0	122	183
IE	M	0	310	37	78	0	23	10	382	840
	F	0	193	29	52		21	12	282	590
Total		0	503	66	130		44	22	664	1,430
MSE	M	0	40	10	17		6		124	200
	F	0	24	10	6	0	5		67	115
Total		0	64	20	23		11	5	191	315
ME	M		406	99	132		51	21	983	1,698
	F	0	87	20	25	0	21	5	196	354
Total			493	119	157		72	26	1,179	2,052
NRE	M	0	15	6	10	0		0	68	100
	F	0			0	0	0	0	15	19
Total		0	18	7	10	0		0	83	119
Polymers (being rolled into MSE)	M	0	0		0	0		0	7	10
	F	0	0	0	0	0	0	0	5	5
Total		0	0		0	0		0	12	15
Undeclared	M	0	17			0			32	56
	F	0	8			0			21	36
Total		0	25		5	0			53	92
Totals			2,616	608	717	9	327	121	4,849	9,253

Table 1: Demographics for majors in the College of Engineering (COE)

The next table shows the graduation rate of Black students at GT.

Cohort group	Grad 4 yrs or less	Grad 5 yrs or less	Grad 6 yrs or less	Grad 7yrs or less	Grad > 7 years
2001	24.5%	61.2%	69.4%	76%	78%
2002	18.6%	64.3%	74.3%	77%	81%
2003	10.6%	53.0%	69.7%	71%	71%
2004	13.6%	61.7%	77.8%	78%	78%
2005	5.7%	48.3%	60.9%	61%	61%
2006	12.1%	56.0%	56.0%	56%	56%
2007	16.4%	16.4%	16.4%	16%	16%
2008	1.6%	1.6%	1.6%	2%	2%
2009	0.0%	0.0%	0.0%	0%	0%
2010	0.0%	0.0%	0.0%	0%	0%
2011	0.0%	0.0%	0.0%	0%	0%

Table 2 – Graduation rates at GT for Black students in the COE

Research Design

To uncover student pathways, strategies and mechanisms that have led to academic success, we conducted a series of semi-structured interviews of twenty-one female and African-American undergraduate engineering students attending GT. Our research approach is grounded in constructivist theory, which argues that people’s truths and realities are not “universally known,” and thus, not objectively measurable. Instead, people’s truths and realities are created “transactionally,” i.e. through interactions and communications with others. Therefore, in this study, the truths and realities of the three students who described their time studying electrical or computer engineering at GT and the coping strategies they developed to succeed are understood to be built from their perceptions, experiences and interactions with others.

The Institutional Review Board protocol for this study was approved on February 19, 2014, and two undergraduate students were hired and trained to conduct the interviews. We chose undergraduates because we surmised that being closer in age and GT students as well, they would be better able to interact with the undergraduates in our study. Both interviewers were female, one Caucasian, the other African American. Interviewees were contacted by the first author and invited to participate on a volunteer basis (no interviewee received anything in exchange of their participation in the study). The first author contacted 26 potential interviewees, and 21 responded positively – the high rate of acceptance is due to the fact that the first author personally knew many of the students. However, the first author never attended a single interview and students all were given (and signed) a Consent Form that explained their rights and how their personal data would be kept strictly confidential and under seal. The interviews were all conducted during the Fall 2014 and Spring 2015 semesters, and are on-going. Additionally, one of the interviewers directly recruited her friends and other students she knew from her campus extra-curricular activities. The third co-author, who helps run a diversity program that supports minority students in the College of Engineering at GT, also recruited students to contact.

Four general research questions informed our interviewing strategy.

1. What experiences and influences led to your choosing GT, a technological institute, and pursue engineering as a major?
2. What has your experience as a minority student been like on a majority campus?
3. Has your minority status been a factor in pursuing engineering as a major?
4. What strategies have you used to succeed in the major?

To arrive at answers to these overall questions, our undergraduate interviewer followed a script from which she could diverge and seek amplification depending on the answers. Below are the scripted questions.

1. Demographic question: How would you describe your age, race/ethnicity, and gender? What is your current college major? What year are you in your undergraduate studies?
2. Can you tell me how you got interested in engineering?
3. How did you decide on GT?
4. Describe your transition to GT from high school.
5. Can you tell me about how you decided on your major?
6. Has that major turned out to be a good choice for you?
7. Have you ever changed your major or thought about changing your major?
8. What is the climate like for women in your major?
9. What is the ratio of men to women in your major and can you share your thoughts on why you have this ratio?
10. As a woman/African American engineering student, do you face any challenges in your major? What are the unique challenges to being a minority student in engineering?
11. If s/he identifies as an African American or Hispanic/Latina woman: do you face any challenges in your engineering major? Can you describe those challenges?
12. What types of support programs have helped you remain in the major?
13. What do you think are the perceptions of women/African American in certain engineering majors vs. other majors?
14. Can you talk about the extracurricular or co-curricular activities you are involved in?

The audio-taped interviews lasted thirty minutes on average. For this paper, we focus on three of the 21 interviewees, two females and one male, chosen for their common major-- Electrical/computer engineering (ECE), acknowledged among the students to be perhaps the most challenging major on campus. We are particularly interested in them given that ECE students are overwhelmingly Caucasian males, so they are most definitely in the minority. Our strategy is to identify major themes of individual and institutional assets related to persistence in an academically very demanding major with very low diversity (at GT, the School of Electrical and Computer Engineering has about 9.78% African-American students, at the undergraduate level, for both genders). They were all interviewed by the same interviewer, an African-American female.

Participant Stories

All names used in this article are pseudonyms to protect the identities of the participants. All three students were eager to share their stories.

Sophie- “Let me just be an electrical engineer because I like coding and electricity”

Sophie is twenty-one and a 4th year junior, originally from Maryland. She was planning to go to college in the North, but attended one of GT’s residential summer outreach programs for minorities and as a result, she decided on GT. Sophie was “always drawn to science class (not math)” and in middle school, declared to her Mom that she wanted to be an engineer. In high school, she took AP physics C and she really liked the electrical C part, so she thought “Okay, let me just be an electrical engineer because I like electricity and coding”. In some respects, she finds the major stimulating but struggles with the stereotypes associated with the major and the field.

I’m not, I guess, your stereotypical engineering student. Most people think engineering students always practice their major, like, I guess for EE’s, we’d probably be making circuits or something in our spare time, blowing up things... but I don’t do that... I just kind of watch TV and sit around... [chuckles] so, sometimes I feel like I should have done something that I actually like to do in my spare time versus something that’s so challenging, that I don’t really have, I guess, a natural knack for... but then other times I think, the material’s really cool, and it’d be awesome if I could work on that, in the future, and if I have to go through this undergrad process to get to all the really cool stuff... so...

Sophie’s GPA is 3.58 (exceptional at this institution), and yet even with this academic success, she does not identify as a typical engineer. Sophie’s true passion, as stated in the interview, is music. She is very involved with WECE (Women in Electrical and Computer Engineering, a student club at GT), Pride Alliance and rugby (the last two she credits for providing a great social life):

Socially, I think, I go to Pride Alliance meetings and stuff like that, they’ve been sort of like a nice, chill, atmosphere to go to, when I need to just, like, total re-socialization, nothing academic, classes, work, [...] it’s nice not to be around EE’s sometimes.

Sophie thought there were 25% women in ECE which is quite generous compared to the actual number (in reality it’s closer to 15% at GT). After graduation she plans to work as an engineer but shows only moderate excitement for it:

I want to stick with engineering [laughs] I want to retire early, though. The plan is to be able to retire by the time I’m 35 [...] and then, if I want to keep working, I’ll keep working, if not, I’m retired! I’ll be taking up a hobby, and maybe going back to school and learning some music stuff [laughs].

Taylor “Running up hill”

Taylor is 21, a 4th year graduating senior, and studies Computer Engineering, the most male-dominated major at GT (by a long shot). She is originally from Roswell GA, with a close-knit family. She has three sisters. Her mother is of Japanese descent and her father is Caucasian. Taylor is very interested in computer science. She credits this interest to a great female AP CS teacher in her sophomore year who got her hooked on coding. She knew after this that she would go into programming. When it came to choosing a field of study in college, however,

Taylor's parents who are both electrical engineers dissuaded her from choosing CS as a major, believing that it was not a practical choice. As a result she chose CompE as her major at GT. Taylor was a cheerleader through all her middle and high school years and did it for a year at GT, but she found it very hard to combine cheering with the CompE curriculum at GT. She also found it very tough being one of very, very few women in the major:

Having to come in, and do a varsity sport, in college, and do my major, and being, like, being like one of the only girls in my major, it was just really hard, just really hard, my first years, and I would say the only reason that I, like, got through it, is because I knew my older sister had done it, and I knew I could do it [...] But one of the big factors was being one of the only girls.

Taylor's older sister studied EE at GT and graduated in 4 years, while being a cheerleader the entire time. So she had her older sister's example to follow, that kept her going in her first two years even when she felt like she was "running up hill". Being one of the only girls made her freshman year really tough. She hates being the center of attention in her classes. In a sophomore-level lab class with a reputation as a weed-out class, all the TAs were male:

I showed up and I was the only girl in my lab section, and all the TAs were guys, and it was just like... I mean... I just felt...and I was a cheerleader at the time and there were times when I would have to go straight to practice so I would be wearing cheer leading apparel like, I just had a really, really hard time in that environment... I remember feeling like Wow! this is just awful to show up the first day and realize I was the only girl but it's a double edged sword to a certain extent because, the TAs learn my name faster, but it's also not good, because then, I felt like, when I'd got my test grade back, they would all know what I got [...] I hated having all the attention on me.

For the most part, she felt that the men were helpful to her, but she's also the type not to ask for help so she's not sure how truly friendly the men really are. She also never went to office hours. She remembers a male professor calling her out in class for being on the phone once, and feeling a lot of anger as she had seen plenty of male students on their phones never being called out, and feeling like she was being singled out because she was a girl. But that happened only once.

She's involved in the sorority Phi Mu which has been good for her and the engineering honor society Tau Beta Pi. When asked about WECE, she acknowledged she receives their emails but has never been to their meetings, even though she would meet a good number of girls there, because she didn't feel like she belonged:

I don't know... It's hard because it's just like, there might be a lot of girls, or there might be an ok number of girls, but, I see them in my classes and I don't feel like I identify with a lot of them, like, you know what I mean, you don't have much in common [...] I just feel very much like a minority [...] I don't know any other computer engineers who's also in a sorority.

While Taylor has done very well academically (she has a 3.86 GPA), she wishes the climate in ECE was less cutthroat, particularly for 1st and 2nd year classes, and she blames mostly professors for that.

Q: And then you said, if you went back to school, it wouldn't be for engineering.

A: Right [...] Part of me is just, like, bitter, because my 1st 2 years were really hard.

After graduation, she hopes to continue in the field she currently has a part-time job in, testing software.

Bob

Bob is 31 years old and ex-military (ex Special Forces). He loved the military and the brotherhood he found there, which he's never been able to find anywhere else, including at his fraternity. After his service, he moved to Atlanta because he had friends there. Before GT he first attended a less competitive local school, thinking he could not attend GT directly. He did very well academically there and then he transferred to GT.

He loved the 1st school best in part because he fit better there (lots of older students, commuter campus). He also was extremely successful academically, maintaining a 4.0 GPA and still had free time on weekends. At GT he feels more rushed all the time in classes, but he does maintain a very good GPA (3.3) and is very involved around campus through groups like LSAMP (Louis Stokes Alliances for Minority Participation), NSBE (the National Society of Black Engineers), and a fraternity. He even founded a veterans group at GT, and also works 22 hours/week at an on campus job, at a research arm of GT. Like Sophie and Taylor, he complains of the difficult classes:

I've never been afraid to go to teachers' offices [...] Some of the teachers here are [...] a lot less approachable [than at his previous institution]. I've had some of my best teachers here at GT, ever, but I've had, definitely, by far, some of my worst teachers here in my life, military, college, high school, life teachers [...] The worst teachers I've ever had have been here at Tech [...] The research-based teacher is a fail.

Like Sophie and Taylor, he finds it essential to do something besides school to maintain sanity:

Learning, as I got here, that I need to make time for other stuff... of course, I need to study, but I will study. I need to make time for other stuff to relax.

Once he graduates, he'll pursue a MS in EE at GT, but only because it's paid for by the research unit he currently works for.

He's not sure what he wants to do afterwards because he didn't have a good experience with his engineering internships so far (four total with two extremely large and well known global engineering firms, mostly doing work that wasn't interesting to him; or where he never felt like he fit in, the culture was too serious and he felt like his direct supervisor left him in the dark, not telling him all he needed to know to get his work done).

How to Persist in Engineering

All of our participants have struggled with the transition to GT from prior school experiences but found ways to be successful in the face of a demanding curriculum. Each has experienced the sense of being different from others in their immediate surroundings – Taylor and Sophie being

female (also Sophie identifying as being homosexual), Bob being non-traditional and older, and both Bob and Sophie being African-American. All three describe an academic environment filled with people who do not look or act like them but is very demanding academically. The end result is that each has developed strategies for persistence and success at GT. We feel there are 2, especially, that have not received much attention in the literature: re-socializing and a means to an end.

Re-socializing

Sophie describes clearly how she doesn't feel like she fits the typical engineering student model, how her passion is for music and that while she has some interest in EE, mostly she doesn't feel like she's a typical EE student. But now that she's vested so much time in the degree, she plans to finish it. She was able to find the right mix of students to support her, and she hangs out with groups which fit and support various aspects of her personality: WECE for academics and professional development, rugby for sports and exercise, and Pride Alliance for a social life.

Taylor describes how she questioned her choice for CompE constantly the 1st 2 years, and only stayed in because her older sister survived a very similar major (at GT, electrical and computer engineering are offered within the same School and students take many classes in common). This reassured her that she could do it too. But she still felt very alone and very much like she was the center of attention within her major, something she was uncomfortable with. In her freshman year, she joined a sorority which has been good for her. Furthermore she participates in Tau Beta Pi for academics and GT for Kids for athleticism and dance.

Bob had other challenges – he is a nontraditional student and significantly older than his classmates. Being in the same fraternity both at his previous school and at GT helped him meet people. He says clearly that working in groups was essential to his academic success:

Really, what I learned is that working with groups is the best thing for me, because I will not understand something and run around in circles on the wrong thing forever [...] If I'm with somebody they'll bust me out that loop, they'll tell me, no, you're looking at it wrong, look at it like this.

He mentioned he goes to the gym every morning before class and studying, which takes care of his daily exercise. He is very involved with NSBE for professional development, his fraternity for a social life, and he created his own Veteran's group.

A Means to an End

All three students stated they will most likely not work as typical engineers after they graduate, or that even if they do, they're not particularly excited about it. This is alarming and helps shed light on why so few under-represented students work in an engineering firm after they graduate. For women, while nationally 18% of engineering undergraduate students are female, only 9% of the engineering workforce is female.

Sophie explicitly says she wants to work as an engineer so she can make a lot of money, retire early, and focus on music. While she may have said this in jest, or with youthful energy and

cheerfulness, it does speak to a deeper longing that clearly went unaddressed for her in college. It is sad that she never found a way to fulfill this while at GT.

Taylor plans to work as a computer programmer, testing software, and while she's still not sold on a specific path after graduation, it seems that a CS degree might have been more valuable. She never got any experience with a traditional engineering firm, and never expressed wanting to. Instead she worked part-time during most of her time at GT in a small, local software start-up.

Bob didn't enjoy his engineering internships and is now considering a sales position with a major engineering firm.

I'm a people person [...] My last internship was with [very large, well known, global engineering firm], in California, but they didn't have anything for me to do [...] It was horribly boring, horribly sucky [...] I can usually click with everybody, just clown and have fun, but that was the first time with a group where I couldn't really catch, like, a groove, a group of people to clown with. I couldn't have fun with a subset of them, and of course, you have to be serious when you're working, but I always want to clown and have fun, [...] I like to get work done but I like to also have fun with it.

We believe this reflects how many of the traditional engineering firms come across as stodgy and unfriendly to this generation of students, and unfortunately this is turning many of them off the field altogether. Even though he's a man, Bob's comments also echo the "Stemming the Tide" report, which showed that most women engineers leave the engineering workforce not due to work-life balance issues (as is often claimed) but due to a hostile, unsupportive environment¹⁷.

Limitations

The narrowness of the work (only three students' stories are presented here, though many more were interviewed) is a clear limitation. This research project was just started within the last year. We hope, with time, to be able to incorporate other students' interviews and provide a richer analysis. If trends across race, gender, and major eventually develop, we plan to administer a survey to target a much larger pool of students. One important factor we haven't considered yet in our interviews is family income level, and how that affects college and major choice as well as persistence.

Another limitation is the fact that all those students attend the same institution, GT. What we gain in specificity and being able to make clear comparisons and conclusions relevant for GT, we necessarily lose in generability. We make no claims whatsoever that our results are directly related to other institutions, especially for those institutions that are very different from a Research 1 university such as GT (teaching-focused colleges, community colleges, HBCUs, etc). Still, we feel our research will be able to provide valuable insight for many majority, selective, 4-year comprehensive universities.

Furthermore, the 3 participants are about to graduate. While it is beneficial that they can provide a complete, or near complete, picture of their time at GT, as well as their path beforehand and the road ahead post-graduation, this creates an additional limitation due to the fact that the study

doesn't show how their feelings may have changed over time, and their growth emotionally, academically and professionally during these highly formative years.

Conclusions

This work looks at the narrative of three students who are members of underrepresented groups at a majority, highly selective, Research 1 institution to understand how they got into engineering and what their strategies were to survive the difficult electrical engineering curriculum. The students uniformly describe demanding professors, a punishing workload, and an environment where they constantly felt alone and different, until they managed to “find their tribe.” (Incidentally, this is not surprising, as most young alumni surveys GT manages uniformly describe a difficult academic environment in all engineering majors). They describe needing to make time for downtime and attribute their success to forming multiple groups that address all aspects of their lives, socially, professionally, and physically.

They also describe not being thrilled with the professional engineering job market, despite graduating from one of the most respected institutions in the country, with a great GPA and a degree that is in huge demand. Maybe some of that is due to the experience of the degree's difficulty still being too raw and painful for them. Still, Bob and Taylor both described internships that weren't challenging or interesting to them. Companies that hope to recruit these highly sought after students would do well to design work experiences that help foster continued interest in those students, when they're still in school and weighing their options.

Future work will focus on expanding the demographics of the participants across majors and race/ethnicity. We also plan to conduct a longitudinal study, interviewing the same students regularly throughout their time at GT, to better analyze how their experience of their time on campus changes as they near graduation.

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