

# Personal and Structural Elements of Support for African American Female Engineers

Delores Rice and Mary Alfred

Texas A&M University

Research in science, technology, engineering, and mathematics, commonly referred to as STEM, is a top priority for organizations across the board. This is because the STEM fields traditionally set the benchmarks for assessing and comparing intellectual capital per country, and this focus trickles down to corporations, institutions, and education systems alike (Science and Engineering Indicators, 2006). Characteristically, the intellectual capital produced by a country is connected to the innovation and advancements made in STEM (Jackson, 2010; National Academy of Sciences, 2007; NACME, 2008; Science and Engineering Indicators, 2006). Therefore, the US production and contribution, as a country, in these fields, is a key measurement of progress, innovation and leadership. Historically, the US leads the race in STEM research and advancements (National Academy of Sciences, 2007; Science and Engineering Indicators, 2006). However, the shrinking talent pool is often noted as one of the challenges, which threaten the US stance as a global leader in STEM (National Academy of Sciences, 2007; NACME, 2008; Science and Engineering Indicators, 2006).

The dialogue surrounding the talent pool is typically centered on recruitment and retention in the K-12 and higher education domains and the associated challenges (Farrell, 2002; National Academy of Sciences, 2007). One of the primary factors impacting the STEM pipeline is the lack of students interested in mathematics and science courses at the K-12 education levels, which negatively impacts the number of students majoring in STEM disciplines at the collegiate level and pursuing STEM careers (NACME, 2008; Science and Engineering Indicators, 2006). Additionally, the Gathering Storm Report, published by the National Academy of Sciences (2007), noted the following factors as challenges for the talent pool:

K-12 student preparation in science and mathematics, limited undergraduate interest in science and engineering majors, significant student attrition among science and engineering undergraduate and graduate students, and science and engineering education that in some instances inadequately prepares students to work outside universities. (p. 121)

Although the recruitment and retention issues are significant topics for the STEM field, there is a need to address the factors that contribute to success for students in STEM in order to better learn from the students who were retained by the field. Addressing the systems of support are especially crucial for underrepresented populations—women and people of color—as those are the groups often targeted, yet who remain a minority in the STEM professions.

The preponderance of literature and research addressing underrepresented populations (American Indian/Alaska Natives, Blacks, Hispanics, and Pacific Islanders) in STEM issues is focused on the K-12 and collegiate pipeline (Gill, Sharp, Mills, & Franzway, 2008; Maton & Hrabowski, 2004; Moore, 2006; National Academy of Sciences, 2007; Russell, 2005; and Vogt, Hocevar, & Hagedorn, 2007). There is little information regarding those who manage to successfully navigate the K-12 pipeline and collegiate domains and find success in professional workplace organizations. Although there is a focus on minorities in STEM, there is a dearth of research and literature examining the career experiences of African American female engineers. Therefore, the purpose of the overall study was to examine the career experiences of African American female engineers utilizing a holistic perspective, meaning that fac-

tors addressing the lifespan were examined. The focus of this study, which is part of the larger study, is to understand the personal and structural factors, which contributed to their support system. The research question guiding the study was: what, if any, were the systems of support impacting the career experiences of African American female engineers?

To examine the career experiences of the African American women engineers, Cook, Heppner and O'Brien's (2005) adaptation of Bronfenbrenner's (1977) ecological model was used as the theoretical framework for the study. The ecological model, as presented by Cook, Heppner, and O'Brien, centers race/ethnicity and gender as key components of career experiences for racial/ethnic minorities and women. Cook, Heppner, and O'Brien (2002) ecological perspective is rooted in Bronfenbrenner's (1977) systems theory, which highlights the influence of the person's interaction with the environment. There are four subsystems in Bronfenbrenner's model: the macrosystem, the exosystem, the mesosystem and the microsystem. While recognizing the four subsystems in Bronfenbrenner's model, Cook, Heppner, and O'Brien (2005) assert that the interactions at the microsystem and macrosystem levels are most valuable for analyzing the career experiences for women of color. The rationale for focusing on these two subsystems is because of the impact of racial and gender experiences at these levels and the corresponding relationship on career progression. Therefore, the ecological framework for this study focuses on the relationship between the microsystem (defined as individual/personal factors) and the macrosystem (defined as factors external to the individual), as both elements impact the career experiences of African American female engineers.

## Related Literature

A dominant discussion in the STEM field is centered on increasing the number of students at the elementary, secondary, and collegiate education levels to consider careers in science, engineering, and other technical fields. Moreover, the majority of the empirical research, whether qualitatively or quantitatively designed, is focused on factors impacting career choice. This discussion is core for all students, understandably heightened for students of color, and certainly for Black female youth. Consequently, researchers attempt to answer the core question surrounding how students select STEM fields, what impacts their decision, and factors that can be addressed to positively impact students considering STEM fields. Although the research in this section is focused on career choice, there were different variables for consideration. The quantitative research covered the role of self-efficacy, barriers, parental influence, and cultural identity (Lopez & Ann-Yi, 2006; Johnson, Stone & Phillips, 2008; Burlew, 1982; McCowan & Alston, 1998). The qualitative research examined the role of the institution and factors considered by African American males (Perna et al., 2009; Moore, 2006).

Lopez and Ann-Yi (2006) surveyed 359 female college students at a Southwestern urban university, which consisted of a diverse racial/ethnic representation and varied academic classification. The purpose was to understand differences in the impact of self-efficacy and barriers (experienced or perceived) on career choice in relationship to race/ethnicity. They hypothesized that Hispanic and African American women would report a lower self-efficacy and more barriers regarding career indecision when compared to White women. Their

findings were contrary to their hypothesis in that they “found no significant between-racial/ethnic-group differences with respect to currently experienced educational barriers, barrier-related coping beliefs, or career decision-making self-efficacy scores” (p. 41). Although African American women were more likely to have higher perceptions of barriers compared to the other groups, essentially, the authors found there was no distinction based on race/ethnicity for the group’s approach to career choice. According to this research, the perception of barriers for African American female college students could influence their decision to pursue a career in the STEM field and present an initial challenge possibly before entering college. Therefore, the perception of barriers should be addressed when dealing with college students and developing strategies to recruit African American females to the engineering field.

Similar to Lopez and Ann-Yi’s (2006) research on career choice, Johnson, Stone, and Phillips (2008) conducted a study to examine the relationship between race, gender, and self-efficacy for African American and female students in the information technology (IT) pipeline. The researchers used quantitative methods by surveying 256 undergraduate students identified as Black or White, male or female. They hypothesized that women and African Americans would have a lower IT self-efficacy than their White male counterparts. However, the findings revealed the opposite. Black students had higher IT self-efficacy than White students, and women reported lower IT self-efficacy levels than men. Since Black students reported a higher IT self-efficacy, the authors noted that there must be a stronger determining factor (besides self-efficacy) for Black students’ career choice and specifically for selecting IT as a career. The authors concluded that self-efficacy was not the most important factor and offered “a number of factors other than self-efficacy—including perceived discrimination, lack of similar role models, and differences in cultural values—may preclude African Americans from pursuing careers in IT” (p. 1015). Based on these findings, the engineering community gained insight into possible challenges that could negatively impact the engineering pipeline in academia and in the professional workplace. Increasing role models for African American women and creating a supportive climate will assist this group in pursuing a career in technology. In examining the research, including Black women in STEM, a dominant theme was career choice.

Another body of work found relevant to research is that of Burlew (1982). While focused on career choice, Burlew’s research differs from the aforementioned studies because her study centered on Black females and added the nontraditional career component. Burlew surveyed 147 Black female undergraduate students to understand the relationship of family role models, environment, and expectations on career choice, and to compare data regarding those who selected nontraditional career paths versus traditional paths. She hypothesized that Black women pursuing nontraditional careers had a higher self-concept than those pursuing traditional careers. The literature referencing nontraditional and traditional terms typically identify nontraditional careers as those fields occupied predominantly by men, which includes the STEM disciplines (Burlew, 1982; Burlew & Johnson, 1992). On the other hand, traditional careers are predominantly occupied by women, for example nursing, education, and social work. In the study, Burlew (1982) found that the role of the mother and her education and career background had a positive influence in women seeking nontraditional career fields. Additionally, she found that Black females were more likely to select nontraditional careers if they had previous work history. Although the research is dated from the 1980’s, the issues presented and found have relevance for understanding today’s women’s career choice and development. For example, Burlew noted that women, specifically African American women, earned less than men, pursued low wage jobs, and were needed in larger numbers in the STEM fields. An additional parallel with her research included the notion that studies on African American women and factors addressing their career development were scant.

Like Burlew (1982), McCowan and Alston (1998) researched African

American women and their career choice. However, they also added the role of identity to the list of factors influencing career decision. McCowan and Alston sought to “examine the relationship among racial identity, African self-consciousness, and career decidedness in first-year and senior women in both historically Black and predominantly White college environments” (p. 28). The authors surveyed 212 African American students at two comparable institutions: one Historically Black College (HBCU) and one predominantly White college (PWCU). The researchers hypothesized that the senior level students at both institutions would have a higher level of insight into their racial identity and career choice. Their findings revealed that the racial identity variable had a stronger association for the senior women at the HBCU than at the PWCU. However, in terms of career choice, they found that the senior women at the PWCU were more confident in their career choice than the women at the HBCU. The implications provided were targeted for college career counselors to help them advise female students of color in their career choice and to consider how their racial/ethnic and cultural identity development may be a factor (whether minimal or not) in their career decision and in their overall identity development. This research sheds light on the importance of the college environment to the college career decision making process, as an external factor, and the association of racial identity, as an internal factor, for young African American female engineering students. The external setting and the internal disposition can serve as challenges for African American female engineers or serve as systems of support.

McCowan and Alston (1998) emphasized the importance of the environment on career choice for African American women and Perna et al. (2009) focused on the environmental factors at a predominantly African American female college with a high success rate for graduating Black female students in the STEM fields. The researchers completed a qualitative case study to examine how one HBCU, Spellman College, contributed to and supported African American female students pursuing careers in the STEM disciplines. The authors interviewed 19 students (focus groups), three faculty members, and five administrators for data collection. Perna et al. found four themes in their research related to Spellman’s support of Black women pursuing STEM fields: (a) the schools rich legacy positively impacts Black women in STEM, (b) the institution supports the student’s solid foundation and future goals, as related to STEM areas, (c) there is a general understanding of the barriers and challenges for Black women pursuing STEM fields, and (d) as a counter to the third finding listed, the institution has systems in place to address the challenges and barriers that Black women face in STEM fields. The study revealed that the combination of these elements provides the support and success structure needed to retain and graduate Black female students in STEM.

While Perna et al.’s (2009) study focused on women, Moore (2006) examined factors, which contribute to African American males pursuing and remaining in STEM disciplines during college. Moore completed a qualitative study by interviewing 42 African American male, junior and senior, engineering students. The following factors were considered prominent in determining the academic and professional path:

- (a) strong interests in science, technology, engineering, and mathematics;
- (b) strong familial influence and encouragement;
- (c) strong aptitudes in science and mathematics;
- (d) meaningful academic experiences and relationships with school personnel; and
- (e) meaningful enrichment programs, opportunities, and academic experiences. (p. 250)

Based on the findings, Moore provided suggestions for secondary education personnel and parents to identify and support students inclined to consider STEM areas. Although the population is not an exact match (according to gender and student variability), the information gained from the research findings adds value to understanding the general dialogue concerning STEM and career factors among African Americans.

The empirical research in this area, although scattered in terms of focus, share some common elements. All of the research was focused on career choice at the collegiate level. Research focusing on the factors influencing career choice for students is valuable in understanding career development for Black females holistically. Additionally, this body of research provides contextual information regarding the influence of background and early academic career factors for the study of African American women in engineering. An additional commonality within this body of research is that there appears to be a minimal relationship between race/ethnicity and career choice. Furthermore, the body of research in this category posits that environmental factors including parental roles, institution, and supporting staff (personally and professionally) are valid constructs for Black women considering STEM fields.

Moreover, the majority of research pertaining to women and racial/ethnic minorities in STEM is concentrated on increasing the pipeline, career choice, recruitment/barriers, and retention of underrepresented groups in the K-12 and collegiate domain (e.g. Burlew, 1982; Johnson, Stone, & Phillips, 2008; Lopez & Ann-Yi, 2006; Moore, 2006; and Perna et al., 2009). Often, in the research and literature, the experiences of racial/ethnic minority engineers are grouped into the same categorical experiences as women, and this discounts the role that race plays in career development. There is little, if any, literature specifically focused on the career development or experiences of African American female engineers, which could provide the missing link in the discussion centered on creating positive change for diversity in STEM.

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systems, specifically the influence of background and early academic career factors. Moreover, the research in this category concur that environmental factors including parental roles, institution, and supporting staff (personally and professionally) are valid constructs for Black women considering STEM fields.

## Methodology

The purpose of this study was to understand the career experiences of African American female engineers. Therefore, basic interpretive inquiry guided this study, using a life history approach (Cole & Knowles, 2001). The life history approach allowed the participants to reveal factors from early childhood experiences, K-12, college, and the professional workplace setting, which provided a holistic view of the participant's experiences and contributing factors.

## Participant Selection

Black female engineers were the targeted group for this study. The factors for inclusion were that the women needed at least 10 years of experience as an engineer, at least one promotion, and currently working in an engineering capacity for an engineering organization. These requirements were utilized to obtain a sample with sustained experience in the engineering workplace. Participants were identified using professional listservs and contacting engineering corporations directly. Additionally, snowball sampling was utilized. The women shared many characteristics. For example, six women attended large, predominantly White undergraduate institutions (PWI) and three attended a Historically Black College or University (HBCU). They were almost equally represented by three engineering disciplines: chemical, electrical, and mechanical. Four of the participants earned graduate degrees in engineering or business. Also, the majority of the women were married with children.

Each participant provided or was given a pseudonym.

## Data Collection and Analysis

Patton's (2002) general interview guide approach was used to conduct in-depth interviewing. The interviews took place at locations deemed convenient and appropriate by the participants. The first round of interviewing took between 90 and 150 minutes. The second round of interviewing was conducted to address follow-up questions or clarify initial points of information. Each interview was digitally recorded and transcribed verbatim, with permission.

There were three phases to the data analysis: first, a case story was produced; second, a thematic analysis was utilized for each case; and third, cross cases analysis was conducted to synthesize themes. The following strategies were used to ensure data trustworthiness: member checking, peer briefing and thick descriptions.

| Name      | Age Range | Under grad College Type | Engineering Discipline | Years in Engineering Field | Grad Degree? | Current Industry       | Family Unit                |
|-----------|-----------|-------------------------|------------------------|----------------------------|--------------|------------------------|----------------------------|
| Christine | 36-40     | Large, PWI, Public      | Mechanical Engineering | 10                         | No           | Aerospace              | Married, two children      |
| Courtney  | 36-40     | HBCU                    | Mechanical Engineering | 10                         | Yes, MBA     | Architectural & Design | Married, no children       |
| Jasmine   | 36-40     | Large, PWI, Public      | Chemical Engineering   | 12                         | No           | Oilfield/ Oil & Gas    | Never married, no children |
| Josephine | 41-50     | Small, HBCU             | Electrical Engineering | 15                         | Yes, PhD     | Technology             | Divorced no children       |
| Lisa      | 30-35     | Large, PWI, private     | Chemical Engineering   | 10                         | No           | Oilfield/Oil & Gas     | Married, no children       |
| Monica    | 30-35     | Large, PWI, private     | Chemical Engineering   | 11                         | No           | Chemical Manufacturing | Married, one child         |
| Nicole    | 41-50     | HBCU                    | Mechanical Engineering | 18                         | Yes, MS      | Research               | Married, two children      |
| Tiffany   | 41-50     | Large, PWI, private     | Electrical Engineering | 12                         | Yes, PhD     | Technology             | Married, one child         |
| Toni      | 30-35     | Large, PWI, private     | Chemical Engineering   | 12                         | No           | Utilities and Power    | Married, two children      |

Table 1. Participant Profile Summary



## Findings

Using the ecological framework, the data revealed microsystem or macrosystem factors at the individual level, family structure, K-12, higher education, and professional workplace settings. The findings within each category are presented accordingly.

### Microsystem Perspectives of Support

There were two common factors presented by the participants at the individual level: self-image and determination and persistence. The dynamic of these factors is detailed below.

**Self-Image.** The role of self-image included how the women felt about their abilities in mathematics and science and their confidence in these areas. The women in the study remembered having a strong affinity towards mathematics in particular, and in some cases, also for science from an early age. Having a strong inclination for math, combined with a curiosity stance for understanding how things worked in the home, led to a positive self-image in early education. The same sentiments regarding math in elementary education carried over into junior high and high school for the participants. Monica shared her accomplishment in high school, stating, "I was very good in calculus. . . it just clicked. . . I was always good in math and science." In addition to the women excelling in mathematics and science courses, they were affirmed by others regarding their academic capabilities. Nicole received words of affirmation from her mother. She shared,

And I think all of that goes back to my mom telling me how I was going to be this great person one day. . . and. . . it starts in the home. If you don't get that in the home, I think it's a lot harder. I still think that you can do it, but I think that if you don't have people at home telling you how smart you are, or how you can do it, or you can do anything you put your mind to, I think it's just a little bit harder because you don't have that internal support that you should have. All children should have it. . .

Nicole's verbal support from her mother provided the necessary motivation when she experienced difficult times academically and professionally. Words of affirmation, which nurtured their self-image as aspiring African American female engineers, were powerful for the participants. The constructive vocal support, combined with their positive internal association and connection to the mathematics and science curriculum in the classroom, proved to create strong self-images and provided powerful support structures for the participants.

**Determination and Perseverance.** One of the underlying mantra's guiding the women was that quitting was not an option, and they adopted a spirit of determination and perseverance. The participants shared stories explicitly stating that they were not going to quit or change their academic plan because they felt destined to become engineers. That is not to say that they did not have obstacles, challenges, or barriers that made them ponder the option to quit. In the end, however, they inherently knew that they could not quit the journey on the path to becoming an engineer. The women were determined to not let obstacles deter them from accomplishing personal success. This mindset served as the ultimate factor in their perseverance. Therefore, when Christine dealt with challenges in her undergraduate engineering program, she relied on her internal determination and perseverance to proceed. She stated,

You know I have been, I'd say, successful in what I tried to do and it's because I don't have a spirit of giving up and so if I would have given up long ago I would have never finished school but I just never gave up. I mean I had to probably repeat a couple of classes, and I just didn't let that stop me.

At their core, the African American women relied on their individual spirit of determination to get them through the difficult times, at each level in their

career. As Toni stated, "I knew I didn't have the quitting spirit," therefore, the women were not going to give up before accomplishing their goals. Because of their determination and perseverance, quitting was not an option for them.

### Macrosystem Perspectives of Support

Support within the macrosystem level included support from family and friends, teacher/counselor assistance, and factors in college and the workplace, which positively impacted the lives of the African American women engineers. The support system factors in the educational environment included teacher/counselor impact, pre-college programs, university resources, and the minority network. The support factors in the workplace included mentors, managerial support and the company structure. Aspects of each factor are presented in this section.

**Family and Friends.** The encouragement and grounding provided by family, friends and significant others played a pivotal role in the lives of the participants from early childhood experiences and throughout college, and continued into their professional experiences as well. Whether the familial support system exemplified tough love or unconditional support, the outpouring of encouragement provided the foundation the women needed for strength and resiliency. The participant's parents valued education and made sacrifices to support their children's education, which nurtured their commitment to education and reiterated the importance of learning.

In addition to the immediate family, friends and extended family members played a key role in supporting the participants. The support from significant others and friends was crucial, particularly in college, when parents and other family members were not immediately available. Ultimately, the women relied on their family, friends and significant others for the motivation to persevere when they wanted to consider other options, or just got tired of dealing with the workload, the difficult coursework in college, or challenging workplace environment. Family and friends provided the stimulus, which kept them going to become the engineers they were destined to become.

**Teachers and Counselors.** The women shared enjoyable K-12 experiences in the classroom with the teachers and received additional support from the counselors. In elementary school, the participants described their teachers as overwhelmingly good because they were nice and caring. Teacher care and concern increased the participant's confidence in their academic pursuits and provided an additional boost for their long-term goals. Josephine had fond memories of her teachers and felt that they cared about the students and their learning because "you actually saw them in the community. And so I actually remember that. . . they all encouraged me." In addition to the teachers supporting the students, the counselors played a pivotal role in the lives of the students, especially in high school. In the K-12 system, the teachers and counselors provided key support systems for the women in terms of reaching their academic goals and getting them involved in extracurricular activities (like academic camps), which would help them in college.

Although most of the participants stated that at the college level, the professors did not show care and concern for their success as a student. There were a few participants who also recalled having one professor who was supportive during their college tenure. For example, Christine described a faculty member who was particularly supportive by stating, "There was one in particular, a Black professor who just really helped me along and was just encouraging." In most cases, the one professor identified by the participants was not in the engineering department. Nevertheless, having at least one faculty member who demonstrated care and concern helped the students to feel welcomed and supported in their undergraduate engineering programs.

For the most part, the participants shared stories where they felt supported, encouraged by, and connected with teachers in the classroom and outside of the classroom in K-12 and, to a small degree, in college. These positive interactions helped the young African American women sustain the often hostile

and unwelcoming engineering environment in order for them to continue their journey on becoming an engineer.

**Pre-College Programs.** Several of the women participated in pre-college programs, either the summer before their senior year in high school and/or the summer before their first semester of college. The pre-college program initiated the formation of the women's supportive peer network on campus and participating in these programs helped them acclimate to the campus before the larger student body arrived. For some participants, the pre-college program was also an opportunity to see students of color specifically and develop community relationships with other minority students before the majority population returned to campus. For example, Monica shared how she transitioned from being one of three 'smart' Black students in high school to joining an enclave of students with similar academic goals and skill sets. This network was especially important for the participants who attended predominantly White institutions, as this was the space to bond with other Blacks, including women, in engineering. However, even for the participants who attended HBCU's, the pre-college program helped them to establish a peer-support system and connect with other like-minded students who were focused on academic success. The pre-college programs provided a valuable network for these women to connect with other students who would support them, challenge them to be their best, and serve as treasured friends, in some instances. In addition to meeting other students, these programs provided a nice transition for the students to get adjusted to life on campus, away from parents, and to establish a routine or adjust to their new life as a college student.

**University Resources.** In terms of resources provided by the university, receiving financial aid was fundamental to supporting the women in college. Regardless of the family structure, whether it was a two-parent household or a single parent, the women relied on financial resources during their college tenure. As Nicole shared, "I really knew my home situation and I didn't want me going to college to be a financial setback for my mom." Consequently, Nicole selected her undergraduate institution based on the scholarship package received and estimated family contribution. Therefore, financial resources were a significant factor in determining the college of choice for the majority of the women. Scholarships from the university in conjunction with funding from independent organizations provided the financial resources needed to cover the majority, if not all, of the expenses during their undergraduate programs. However, financial resources were not the only way the university supported the women in obtaining their degree. In addition to providing financial aid, university programming, offices, and efforts on campus assisted the students with accomplishing their academic goals. Tiffany's university offered programming specifically for students in engineering. She noted:

But the one thing they (the university) had working for them, I think was great help for the students, was first they had a (support services) program, it was...for minorities in engineering...and they targeted bringing in minorities and supporting them through the engineering program. So it was all different areas within engineering but they provided workshops and tutorials. Like workshops in physics and math, because a lot of the students coming in didn't have those prerequisites, so they didn't have a strong background in those areas...so we had a person come in and actually provide all of our tutorials in the physics area and math...we started dominating (in those courses) and doing very well.

These types of programs and initiatives at the university and college level communicated to the students that the university cared about their progression in the engineering program. In addition to programming, having a dedicated office on campus in the engineering program further contributed to the academic and personal success of the young African American female college students. Lisa shared:

It was, just knowing that you could go in (the support office) and ask a question and someone would try to help you. The other part is I became a tutor for that group and so that allowed me to have some spending money and allowed me to meet other students outside of the (pre-college) program that I had participated in. It was a social avenue as well, you know it allowed me to meet, let's say the senior who was getting ready to finish in electrical engineering otherwise I would never meet that person... So it gave me an opportunity to meet people that I probably would not have otherwise made an effort to talk to.

The on-campus support provided by university administrators served as a surrogate familial support system in terms of motivation and encouragement. The university services, from financial resources to human resources, were instrumental in engaging the students and creating positive connections to the university. Ultimately, these connections and resources helped to retain the students in the program.

**The Minority Network.** The peer community, consisting of minority groups, served as the women's primary source of support on a daily basis. Their peer relationships provided assistance dealing with the academic and environmental challenges in their respective colleges and universities. The participants shared stories regarding the importance of finding groups of people who shared common goals, namely to graduate from college. Consequently, an energy current developed with their peers, which thrust the group to keep making progress, despite challenges and barriers. Courtney stated, "it's like we're all there for the same goal. And so I think you just pretty much (get) pushed by the entire environment." The peer environment was substantial in supporting the academic goals and success of the participants. In describing the peer environment at her school, Tiffany shared, "I just got with a set of people who were succeeding. And I just wanted to succeed too." These enclaves were also beneficial for study sessions. Nicole noted:

And then, of course, we had our little clique of students that were the honors students, we all studied together. We figured that out real fast, we figured out which students were good in which classes and those were the students that kind of led little mini study sessions... I mean we formed a tight little knit that was our support group.

Much like the university administrators represented a familial support system, the peers and subsequent peer groups represented mini families as well. In most cases, the minority peer group consisted of other African American students in the engineering program. However, sometimes the minority network consisted of other women or other racial/ethnic minorities. Josephine shared how her minority network was formed as a result of negative experiences with White students in her classes:

So now you can imagine my first quarter there, and I'm like, I have to get a team and nobody wanted me to be on their team. With one exception, and it never failed; it happened every class, the students from other countries, who were of color. The first time one of them came to me, and said to me, they were being rejected just like I was, and came to me and said 'you know I'm being rejected by my classmates, no one wants me to be... a part of their team, and so I'm just assuming that the same thing is happening to you, is that true? They said 'yes' (and I said) 'so why don't we get together and have our own team' and so that's what happened.

The minority peer network included forming strategic relationships with other students who shared the minority status. One of the primary drivers for the minority network particularly at predominantly White colleges was the National Society of Black Engineers (NSBE), an engineering student organization. The participants each shared stories affiliated with NSBE and how their initial network established as a result of being involved in NSBE. NSBE was often noted for providing the opportunity for the African American college stu-

dents to gather and support one another on the journey. In addition to NSBE, the other African American and/or minority student organizations on campus provided support as well. The minority peer network was a key component in supporting the African American female students and their efforts to succeed in the engineering program. Some universities provided programming and/or offices in the engineering department dedicated to minority affairs, and student organizations like NSBE to assist with transitioning to and graduating from the university. These networks proved to be invaluable for the participants.

Before entering the college environment, the women relied on family and friends and teachers and counselors as primary systems of support in their career development. In college, they participated in pre-college programs, utilized university resources and the minority network. Moving into the professional engineering workplace, the participants stated how mentors, managers, and the company structure supported their career experiences.

**Mentors in the Workplace.** As the women graduated from college and transitioned to the engineering workplace, they sought out a supportive network similar to their collegiate peers. To this end, mentors were valuable for the African American female engineers. Largely self-selected, the mentors helped to guide their careers and supported the women as they sought to advance in their profession. Josephine shared how her mentor helped direct her to consider a different functional area of their high-tech company to gain experience that would benefit her in her role as a researcher. The new position also provided exposure for future roles within the organization. She trusted her mentor; she also stated her mentor “knew the politics, she knew how things worked.” Therefore, mentors were able to provide guidance as the women navigated the engineering culture overall and within their specific engineering organizations. The mentoring role was so valuable to Josephine that she makes it a personal point to stress mentorship to young professionals, in addition to serving as a mentor. She stated:

So, I tell, particularly young people now, mentoring is extremely valuable. You’ve heard the adage time and time again; it’s not what you know but who you know. Well actually you have to be competent, that’s a given, that’s the foundation but it’s not enough to be competent. You really do have to have mentors who are in positions of power and influence, who can guide and direct and make things happen for you when you are competent.

The participants shared their stories regarding the importance of having a mentor who supported their career vision or provided vision and believed in their success as an African American female engineer. Although the mentors represented varied race/ethnicities and were male and female, the common goal that they shared was providing committed support to the women. Having mentors with influence were equally valuable as having managers who provided support for the women.

**Managerial Support.** Managerial support was just as significant as a mentor in the professional lives of the African American female engineers. The managers provided resources for their current projects and interests, assisted with personal issues, and supported their career development. Managerial support and flexibility in work scheduling kept the women engaged and connected to engineering while balancing commitments outside of the workplace.

In addition to supporting the women from a work/life balance perspective, managerial support extended to recognizing the women as top talent within the organization and nurturing them as rising engineers. Because of Monica’s relationship with her manager, she was nominated and selected to participate in an internal company program for high performers in the chemical manufacturing industry. She described the benefits of participating in this program and the long-term advantage of being in the network, all as a result of her supervisor at the time. She stated:

So I got training, I got access to mentors, and then I got to be on projects that I probably wouldn’t have been on before and I really credit this boss.

. . . I mean I told her I’m interested in mergers and acquisitions. . . from an environmental standpoint. So she gave me a project for a very small acquisition where I was their main contact. And then once we made this very large acquisition of (another company), she put me on that team, and that opened up a lot of opportunity that I probably wouldn’t have had before.

Managers can play a pivotal role in career progression by creating opportunities for visibility and development. In most cases, the managers described by the participants were the ideal managers for supporting career growth and development. They provided opportunities for the women and assisted with expanding their professional skills. Although every manager did not fall into this category, the majority of the participant’s experiences included having helpful managers in their support system at the workplace.

**Company Structure.** The organizational structure was considered supportive largely because of the flexibility of the company in supporting their values, career goals and interests as a person and an employee. Being self-initiated regarding her career goals, Jasmine appreciated her company’s fluid perspective toward career development and career management. She joined a company culture, which resembled her personal approach to career development regarding movement, fluidity and frequent challenges and opportunities. The company structure, combined with a strong network of mentors and managers, supported all of the women and their self-initiated career progressions. Moreover, these factors served as significant retention tools for these organizations. Ultimately, these systems of support contributed to retaining these top African American females in the engineering field.

## Discussion

The purpose of the study was to examine the factors, which served as support systems for the African American female engineers. The ecological framework provided the theoretical underpinnings used to examine the data, specifically the microsystem and macrosystem factors that contributed to the career experiences of the participants. Figure 1 provides a graphical representation of the two primary categories and subsequent findings.

### INSERT FIGURE 1 HERE

#### Microsystem Perspectives of Support

The primary factors in the microsystem were having a strong math and science self-image combined with an internal spirit of determination and perseverance. The messages the participants received about their intelligence and natural abilities in mathematics and science gave them confidence and nurtured their self-image. The participants were secure in their capabilities in math and science from early childhood and their image continued to be affirmed throughout their education. Consequently, the foundation was established for them to forge ahead in the engineering pipeline. Gill, Mills, Franzway and Sharp (2008) noted similar findings in their research on high achieving women in the workplace. This data supports other research in this area, which notes the importance of having strong capabilities in math and science disciplines, which leads to greater confidence in the classroom and in the pursuit of an engineering degree (Goodman et al., 2002; Levin & Wyckoff, 1991). Other literature related to this topic often refers to women’s self-efficacy and self-concept interchangeably, as it relates to the environment (Bonous-Hammarth, 2000; Lam, Doverspike, Mawasha, 1997; Wender, 2004). Specifically, it is noted that the environment can affect the person’s confidence and identity, which can support or hinder women pursuing careers in STEM (Gill, Sharp, Mills & Franzway, 2008).

Despite the challenges they experienced along the way, the women were determined to persevere; therefore, quitting was not an option. Of course, they



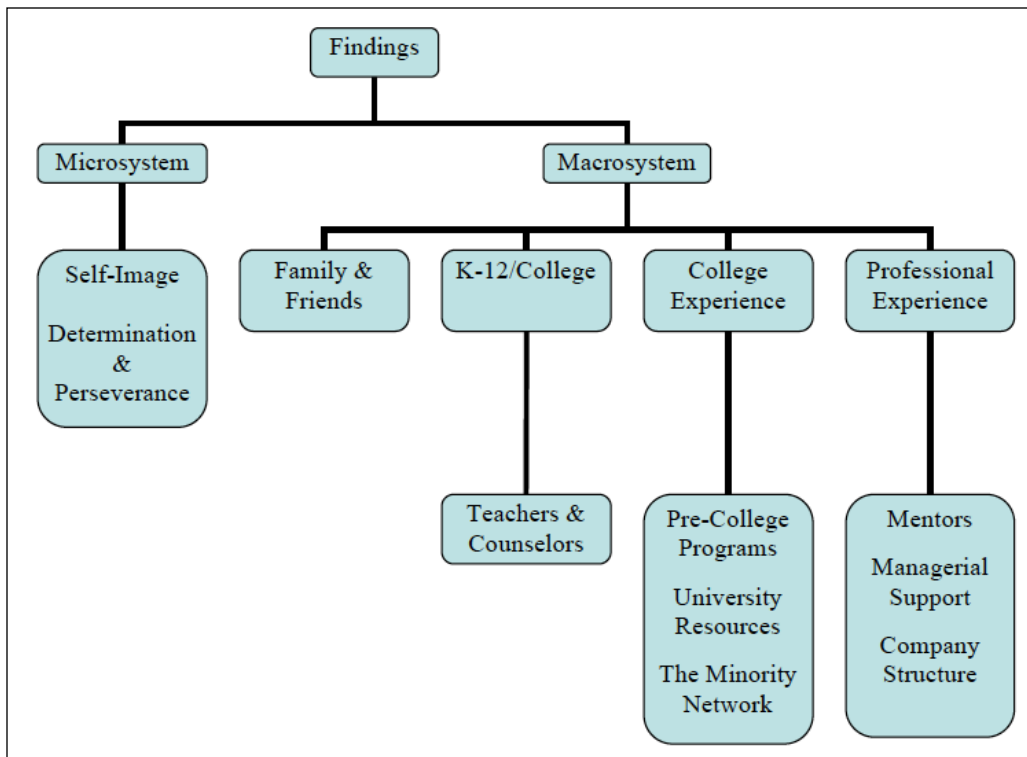


Figure 1. Graphical Representation of the Research Findings: Support System

could have stopped the journey at any point. However, in their mindset, there really were no other alternatives. Levin and Wycokoff (1991) studied factors, which impacted persistence in engineering programs. There were two types of students discovered: those who persisted and graduated from undergraduate engineering programs, and those who decided to pursue a different course of action. They found, “these two types of students, successful non-persisters and successful persisters, illustrate that doing well in engineering is not merely a function of only academic ability or only interest. Instead both ability and interest must interact for successful persistence to result” (p. 466). For the participants, their determination to succeed certainly advanced their interest in the field. They were determined to persist and make their goal of becoming an engineer a reality.

### Pre-College Macrosystem Perspectives of Support

The macrosystem included several factors, which supported the women’s career experiences, from childhood experiences to their current workplace organizations. Those factors included family and friends, teacher/counselor support, pre-college programs, university resources, the minority network, managerial support, and the company structure. Initially, the foundation for support was established by those closest to the women, that is to say their family and friends. The family unit was significant in providing the groundwork for the importance of education in the household. Family and friends were critical for providing informal learning and support outside of school and for providing encouragement during the schooling years.

Each of the participants knew they were going to college from an early age and knew that the family unit would support their efforts every step of the way. Therefore, the participants shared information complementary to the research presented by Goodman et al. (2002), particularly regarding the important role played by the family. They found:

Most students made the decision to major in engineering before they entered college. Mothers and fathers were highly influential in students’ decisions about the major, with more than 70% of respondents citing a parent

as the most or second-most influential factor in their decision to pursue engineering. (p. 167)

Correspondingly, the Catalyst (1992) report stated the importance of exposing girls to engineering at an early age. Etzkowitz, Kemelgor and Uzzi (2000) reported the influence of parents, especially fathers, in supporting education and careers in STEM. The participants noted that their fathers were instrumental in introducing them to informal engineering concepts. Likewise, both parents were clear about expectations for them to do well in secondary education and to continue making progress in college. The positive support, feedback, reinforcement, and support from family and friends contributed to the women’s development in engineering.

Whereas family and friends supported the women outside of the classroom, teachers in the K-12 education system had a profound effect on the lives of the young female students. The participants noted how their teachers took an active interest in their lives inside and outside of the class-

room. Additionally, the counselors showed a similar care and concern about the student’s success. Goodman et al. (2002) found that teachers in secondary education are credited for encouraging women to pursue engineering. They noted:

Teachers and guidance counselors can play an important role in guiding students to consider and prepare for an engineering career. Exposing girls in elementary school and middle school classrooms to engineering on a more widespread basis could help increase the numbers of women entering the major in college, and guidance counselors could also play a natural role in guiding or at least exposing female students to engineering and getting them to consider the field. (p. 176)

Likewise, Gill, Sharp, Mills and Franzway (2008) and Gill, Mills, Franzway and Sharp (2008) noted the important role that teachers play in encouraging women to pursue STEM fields.

In the education system, particularly K-12, students explore their natural abilities, interests and skills. The teachers and counselors guide the students on their journey and have the ability to nurture and support student learning. For the participants in the study, the teachers and counselors were key factors in developing their academic interests, particularly in STEM.

### Macrosystem Support in College

After graduating from high school, the women’s participation in a pre-college program was important in building a support system in college. In addition to establishing a support system, pre-college programs are specifically beneficial for students of color by contributing to their retention and success in STEM disciplines (Maton, Hrabowski & Schmitt, 2000; Palmer, Davis, & Thompson, 2010). Pre-college programs, particularly the summer before the first year of college, assisted with the transition from high school to college, academically and socially. One program that has been particularly successful with retaining students of color in STEM and getting the students to not only graduate with undergraduate degrees, but also to pursue graduate STEM degrees, is the Meyerhoff Scholars Program at the University of Maryland. Three

key components of the program include the summer bridge program, study groups and program community. The Meyerhoff Scholars Programs and other related programs are proving to be successful in retaining minority students in STEM (Palmer, Davis & Thompson, 2010). These programs include the elements that the participants stated were beneficial as women of color pursuing an undergraduate degree in engineering. Often, during the undergraduate experience, peer groups were the primary factor in their support systems. Therefore, these programs helped the women acclimate to life on campus and to form their system of support with upperclassmen and their peers. In addition to providing pre-college programs, universities needed to provide additional resources to support these women.

University resources, largely financial and human resources, at the college or university level provided substantial support to the women. Initially, securing money for college was a key factor in determining which institution the participant attended. Financial burden, particularly for African American students, is often noted as a challenge for persisting in college. Thus, securing funding to attend college was vital and it allowed the student to focus on academic issues versus financial challenges (Lam, Doverspike & Mawasha, 1997; Maton, Hrabowski & Schmitt, 2000). Moreover, support offices on-campus, specifically for minority students in engineering, provided additional opportunities to earn supplemental funds while in school by working as a tutor or student employee. However, the most important resources were the staff working in the on-campus support offices. They provided the familial connection, encouragement and support resembling the family unit in the home. Some college programs offer dedicated counselors to work with students on academic matters and oftentimes include counseling on personal situations (Maton, Hrabowski & Schmitt, 2000, p. 633). Staff members on campus provided the backbone for the students as African American women in engineering. For the colleges and universities who provide these resources, it represents institutional support to the student and an interest in their success in the engineering program. Moreover, the university resources, in some cases, were instrumental in connecting the student with other minorities.

The minority network provided support for the participants during their college tenure by joining them with peers who shared common goals. The women noted that they became focused on accomplishing their goals at the university, and their peers shared common goals. While the participants were at predominantly White institutions (PWI), the minority peer group largely consisted of other African American students in the engineering program. Yelamarthi and Mawasha (2010) stated, "Building communities for minority and female students in STEM is particularly valuable, as these students tend to feel relatively isolated in programs where they have traditionally been underrepresented" (p. 68). Feelings of isolation and exclusion were no different for the participants, as they shared stories where they represented the only person of color and/or woman in the engineering classroom. Therefore, the value of peer groups, particularly for students of color is highlighted whether via mentoring, formal programs, or other peer networking opportunities (Tate & Linn, 2005; Budny, Paul, Bateman & Newborg, 2010; Maton, Hrabowski & Schmitt, 2000; Goodman et al., 2002; Lam, Doverspike & Mawasha, 1997). Peer networks are invaluable because, "in addition to offering social, emotional, and educational support, the clustering of incoming students into common sections serves as a buffer against "solo" or "token" effects" (Lam, Doverspike & Mawasha, 1997, p. 63). Additionally, the peer network served as a basic support system, which also included studying together, challenging one another, supporting everyone, learning collaboratively, and most importantly, connecting. Oftentimes, the minority student organization, the National Society of Black Engineers, served as the hub for the minority network. Brown, Morning and Watkins (2005) stated that the majority of African American students are members of NSBE and/or participate in NSBE programming and events. Regardless of the group, whether formal or

informal, the network was found to be a positive force in the supportive system.

### Macrosystem Support in the Workplace

Similar to the established peer network on campus, mentors provided advice and guidance for the women and their career path in the engineering workplace. The Catalyst (1992) report examined success factors for women in engineering and reported:

Nevertheless, nearly everyone agreed that coaching and advice from someone other than one's supervisor often make a critical difference in one's career advancement. This type of knowledge sharing often helps junior employees understand informal cultural rules and corporate politics, and provide a broader view of technical subjects. (p. 37)

In a follow-up report, Catalyst (2004), reiterated the importance of mentors in the workplace. Specifically, for this targeted group, the report noted:

Three-quarters of African-American women report having a mentor as key to success. Among the women of color surveyed, African-American women are the most likely to have a mentor: 38 percent of African-American women surveyed have a mentor, compared with 33 percent of Latinas and 27 percent of Asian women. (p. 23)

As the literature indicated, having a mentor was a key component to the women transitioning from college to the workplace, as well as the continued development of their career. The participants' mentors served as coaches, counselors and champions for the women. Whether formally or informally, male or female, or African American or another race/ethnicity, the mentors played a central role in the career experiences of the African American female engineers. Workplace organizations seeking to retain top talent will need to provide and support mentorship for African American female engineers.

In addition to mentors, supportive managers in the workplace were also significant support systems for the women. For some participants, the manager acted as a counselor, and in other cases, the manager created opportunities for the woman to progress her personal career plan. The Catalyst (1992) report noted that some women engineers contributed their advancement in their careers and their success to the support received by their managers. Moreover, "Many African-American women report achieving positive relationships with managers and coworkers. They also report receiving support and coaching from other women of color in the workplace" (Catalyst, 2004, p. 23). From developing leadership and technical skills to issuing relocation packages for personal matters, the managers were top notch in putting their employees first. The participants' managers demonstrated care and concern for the African American women in the workplace. Furthermore, these are the management characteristics that will continue to support these women and other women of color in the engineering workplace.

The African American female engineers were self-directed and ambitious. They had, and have, career goals that are varied within and beyond engineering. Therefore, they considered their company structure as a support system because it allowed them to explore options and opportunities in different functional areas within the company. Many companies offer rotational programs or structured development programs, which are beneficial to employees and their future success within the organization (Catalyst, 1992; Gill, Mills, Franzway & Sharp, 2008).

Participating in structured development or rotational programs, or being allowed to informally craft a career plan allowed the participants to learn about their company's culture, the organizational dynamics, and the many different opportunities available to them. The company structure supported their multiple interests and diverse backgrounds. The women enjoyed having options and exploring alternatives within the company structure. As a result of the organization's flexibility regarding career planning, the women remained engaged with the company and the engineering field overall.



## Significance of the Study

This research seeks to make a significant contribution to the research, practice, and policy regarding engineering education, specifically for African American female engineers. Research and literature addressing the career development of Black women in the workplace are scant, relative to White women whose patterns of work and living are typically generalized to those of Black women (Phillips & Imhoff, 1997). Moreover, research addressing Black women in engineering is nearly non-existent. Due to the dearth of information on the career development of Black female engineers, information is pulled from a general perspective with regards to women's career development and is often examined according to the dominant group. As a result of limited perspectives, researchers made a call to include more voices from women of color in career development literature and this research answers the call (Fouad & Byars-Winston, 2005; Thomas & Alderfer, 1989).

This research contributes to practice in terms of increasing diversity in engineering specifically and STEM overall. This research informs teachers and leaders in K-12 education, as to the early childhood educational experiences that had a significant influence on the African American female participants. In order to increase the pipeline for students pursuing STEM careers it must be understood that such experiences go beyond having an interest in mathematics and science as the primary contributors to a career in an engineering profession. Additionally, this research informs faculty and staff and their leadership in colleges and universities as to the systems that serve to recruit and retain this targeted group in engineering. Finally, this research informs STEM professionals and their leadership in corporations by providing career development elements that retain and support African American female engineering professionals. This component includes strategies that workplace organizations can adopt to support African American female engineers and other underrepresented groups in STEM to be successful in the engineering industry.

In addition to contributing to practice, this research also seeks to impact education policy regarding diversity in STEM. Specifically in higher education, this research informs policymakers regarding the importance of funding for STEM education. It is critical to provide funding for support programs, in areas like tutoring, mentoring, and experiential education, in order to assist African American female engineers pursuing engineering majors and careers.

The number of women and students of color entering and graduating engineering programs, and then successfully transitioning into STEM professions needs to increase in order for the U.S. to continue to be competitive in engineering and technical disciplines. Research on the career experiences of African American female engineers makes a positive contribution toward establishing gender and race equity and diversity in engineering.

## Conclusion

The findings in this study substantiate the vital role played by support systems at the microsystem and macrosystem levels for African American female engineers, which is the very reason why they are currently working in engineering roles for engineering organizations. It is critical to note that these women were supported in every phase of the pipeline, from early childhood, during elementary and secondary education, college, and even today in the workplace. Oftentimes, the engineering community focuses on one area of the pipeline to positively impact change and increase participation in STEM. This approach misses the mark.

For those truly interested in increasing minority representation in STEM, adding support systems throughout the pipeline will be vital to minority recruitment, retention and success, particularly for African American female engineers.

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**Dr. Delores Rice** is an Assistant Professor in the Department of Educational Leadership, College of Education and Human Services at Texas A&M University – Commerce. She serves as the Program Coordinator for the Texas Affordable Baccalaureate program, which is a groundbreaking competency based degree program led by the college. In addition to teaching and supporting the university, Dr. Rice conducts research in STEM (science, technology, engineering and mathematics), with a passion for engineering education and social justice. Having earned a bachelor of science in mechanical engineering, her research focuses on African American female engineers and other underrepresented groups in the STEM disciplines.



**Dr. Mary Alfred** is Executive Associate Dean and Professor of Adult Education and Human Resource Development in the College of Education and Human Development at Texas A&M University. Her research interests include learning and development among women of the African Diaspora, sociocultural contexts of migration and adult learning, welfare reform and economic disparities among low-income adults, and issues of equity and social justice in higher education and in the workplace. She received her Ph.D. in Educational Administration with a focus in Adult Education and Human Resource Development Leadership from the University of Texas at Austin.

