

**INSIDE THE DOUBLE BIND:
A SYNTHESIS OF EMPIRICAL RESEARCH ON WOMEN OF COLOR IN
SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS**

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SECTION ONE: THE NATIONAL LANDSCAPE OF WOMEN OF COLOR IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS

Improving recruitment and retention in science, technology, engineering, and mathematics (STEM) is a critical challenge facing the nation. In an increasingly globalized world, scientific advancement and innovation are vitally important for maintaining national security, economic competitiveness, and quality of life for our citizens. The United States faces serious threats to its global authority in many scientific and technical fields, in part because of the large investments in science and technology education and research being made by competing nations (National Academies, 2006). One critical component of the U.S. response to these challenges must be to invest in the potential of *all* Americans in building a robust workforce in STEM fields. Unfortunately, the current U.S. educational and research infrastructures fail to do this, and they systematically under-utilize important human resources of several groups, most notably women of color. As national demographics of college-age students rapidly shift towards majority-minority and as the college-age population remains majority female, it is timely and, perhaps, imperative that education and career efforts work to build capacity of women of color to assume advanced STEM positions.

Because of their race, ethnicity, and gender, women of color who pursue advancement through STEM fields are caught in a double bind. The challenges of living at the intersection of race and gender were first brought to national attention by Shirley Malcom, Paula Hall, and Janet Brown, in their seminal 1976 American Association for the Advancement of Science report, *The Double Bind: The Price of Being a Minority Woman in Science*. The authors argued that the struggles to be scientists were greater for women of color than for White women or for men of any color. Thirty years later, the persistently low proportions of women of color in STEM support this claim. Even as underrepresented minority (URM) women – African American, Latina/Chicana, and Native American² – have gained representation in STEM in absolute numbers in most fields since the publication of *The Double Bind*, they lag behind white men and their men of color counterparts at advanced stages of most STEM fields (NSF 2009). Moreover, their 2006 proportional demographic presence at the baccalaureate level is low compared with those of White and Asian American women (Figure 1.1; NSF, 2007; U.S. Census Bureau, 2009). In other words, the awarding of bachelor’s degrees to URM women is *not at parity* with their respective representations in the U.S. population.

² For a more detailed explanation of racial/ethnic terms used in this paper, see the section, “On Terminology,” p. 11-12.

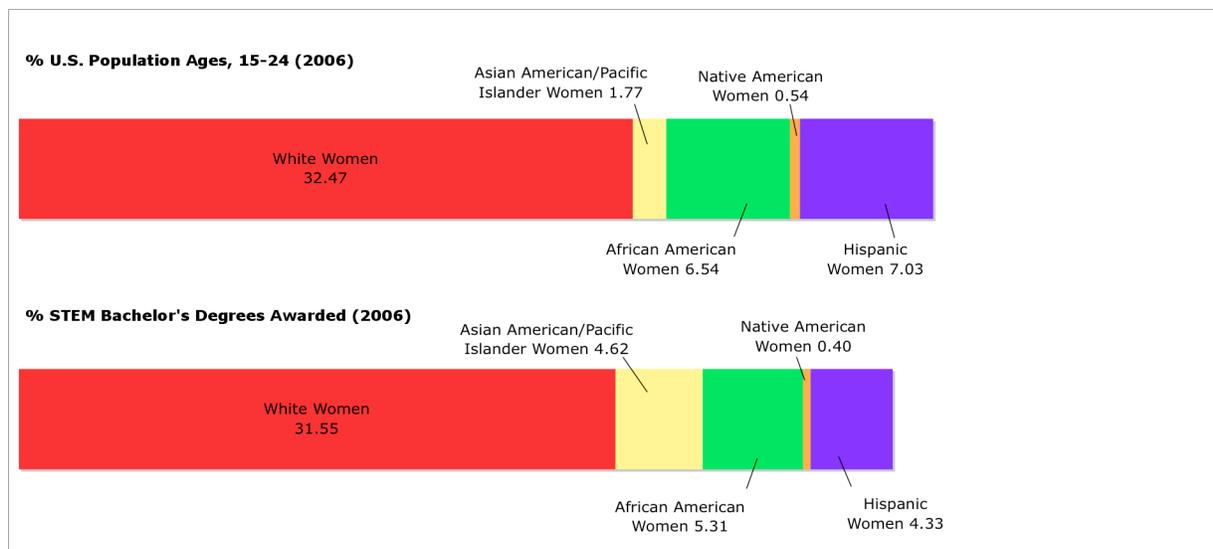


Figure 1.1. 2006 Female U.S. Population (Ages 15-24) and STEM Bachelor's Recipients for Selected Racial/Ethnic Groups

Unfortunately, the problem is even more severe at the doctoral level when comparing the representation of women of color in STEM to that of all men, to white women, and to women of color in the U.S. population. At the Ph.D. level in 2006, women of color were severely underrepresented, collectively earning only 9.9% of all doctorates awarded in science and engineering while their representation in the general U.S. population was 16.4% (Figure 1.2; NSF, 2007; U.S. Census Bureau, 2009). Asian American/Pacific Islander women have often been seen as the exception; indeed, 2006 data show that they earned STEM Ph.D.s at a disproportionate rate relative to their general U.S. representation. However, this group – like other women of color – have been, and continue to be, stuck at junior-level positions and are not advancing to leadership positions at the same pace as their male and White female counterparts (National Research Council, 2006).

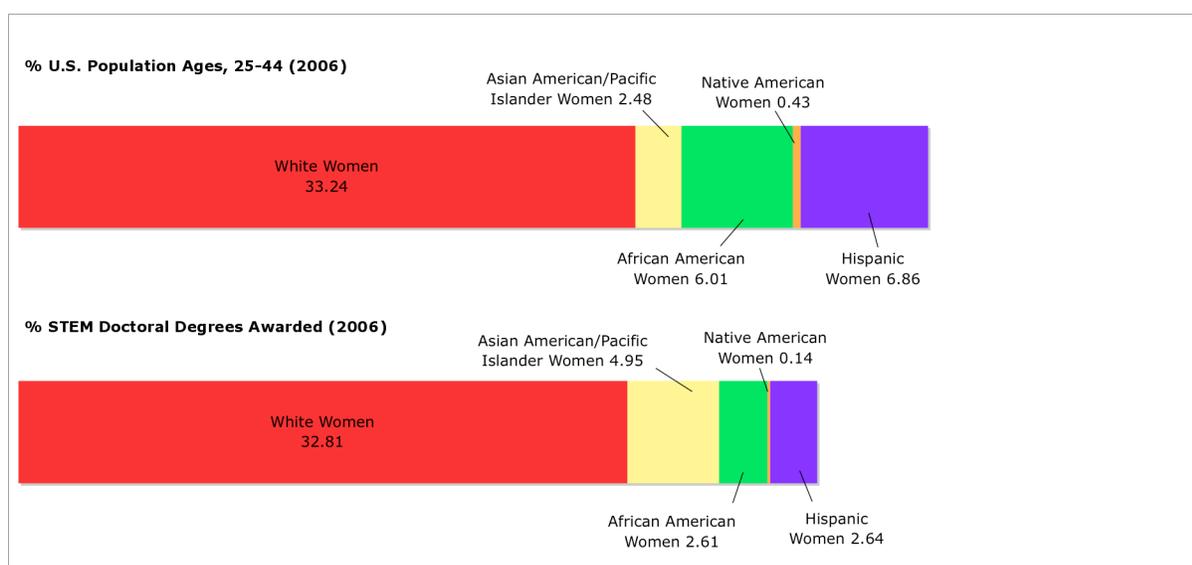


Figure 1.2. 2006 Female U.S. Population (Ages 25-44) and STEM Ph.D. Recipients for Selected Racial/Ethnic Groups

Women and racial and ethnic minorities, and especially women of color, are widely considered to be untapped sources of domestic talent that could fill the country’s current and future scientific workforce needs (Ivie & Ray, 2005; National Academies, 2006). Moreover, non-traditional students and workers bring to STEM culturally different knowledge and experiences that may be leveraged to innovatively solve complex problems (Bement, 2009). Equally important, minority women’s status in advanced STEM arenas raises an important social justice issue: schools and workplaces must make greater efforts to address social and cultural inequities and to achieve environments that support broadened participation in STEM (S.W. Brown, 2000). While many institutions attempt such efforts, the statistics cited above show that too few are succeeding.

The goal of this white paper is to unite disparate research about the individuals who traverse the double bind and the programs and institutions with which they interact, thereby creating a new and stronger knowledge base about what promotes success for this population. The project, *Inside the Double Bind: A Synthesis of Empirical Research on Women of Color in Science, Technology, Engineering, and Mathematics (NSF-DRL # 0635577)*, brought together a team of expert researchers towards this goal. Between 2006 and 2009, the project team, led by PI Maria Ong and Co-PI Gary Orfield, systematically searched for, identified, and compiled empirical research on women of color in STEM that was produced between 1970 and 2008. The team targeted literature that focused on postsecondary education and early-, mid-, and late-career stages. The resulting 116 works were then coded, analyzed, and synthesized. This paper presents a summary of key findings, following the methods section. It is our hope that this manuscript will provide new and established researchers a literature base from which to work and prompt ongoing awareness and discussion of the need to address the experiences of women of color in STEM through continued empirical-based study.

SECTION TWO: METHODS

Data Collection Sources and Methods

The *Inside the Double Bind* synthesis project was cross-disciplinary, delving into empirical research done across the social sciences (e.g., higher education, sociology, psychology) and STEM disciplines, particularly reports and papers coming out of – and directed towards – the STEM community. The project team conducted an extensive, year-long literature search on multiple levels of STEM education and careers: undergraduate, graduate, postdoctoral, early entry, mid-career, and leadership career positions, as well as the broader notion of an education and career STEM pathway.

Beyond a traditional library search, we conducted searches of 48 electronic databases and clearinghouses (e.g., ERIC, PsycINFO, JSTOR), dissertations searches (UMI ProQuest), and general internet searches. We also sent out over 125 calls at national conferences (e.g., AAPT, NARST, ASHE), to listservs (e.g., WEPAN, NSF Research on Gender in Science and Engineering), and to special interest groups working in areas of gender/sex, culture, race/ethnicity, and/or STEM (e.g., Committee on the Status of Women in Physics). Furthermore, we sent direct inquiries to organizations (e.g., Kirwan Institute, SACNAS, MentorNet), editors of journals (e.g., *Journal of Women and Minorities in Science and Engineering*, *Gender & Society*) and individuals identified as working on the topic of women of color in STEM.

Data collection initially supplied 634 citations and documents. Our team then focused on filtering these documents according to stricter parameters: *Only empirical works³ that specifically addressed the status and/or experiences of U.S.-born women of color were retained in the final pool of literature for analysis.* The team selected a time frame of literature produced since 1970, in order to capture scholarship about the political and social contexts that led up to *The Double Bind* (1976), as well as work that has been produced since this seminal report. The team excluded materials on K-12 education, professional schools (e.g., medical, veterinary), foreign (non-U.S.) students and employees, foreign school and employment systems, and Congressional hearings.

The filtering process for eligible literature yielded 116 empirical research documents.

Document Descriptions

Team researchers examined the 116 documents, which consisted of peer-reviewed and non-peer-reviewed studies, research and evaluation reports, published books, conference papers, and unpublished dissertations. The tables below summarize key features of the empirical documents identified.

³ For the purposes of our study, we defined “empirical work” to be: *A work that presents a research question, research design, data collection and analysis, findings, and answers to the research question. Empirical works can be qualitative, quantitative, or mixed methods.*

Table 2.1
Characteristics by Race/Ethnicity

Race/ethnicity	Number of Documents	Including White Women	Multiple Race/ethnicity
African American	98	20	87
Chicana/Latina	67	23	55
Asian American/Pacific Islander	45	16	40
Native American	43	20	42

Note. Columns do not add up to total count of 116 since there may be more than one race/ethnicity per document and since not all documents included White women.

Table 2.2
Characteristics by Objects of Study

Objects of Study	Number of Documents
Students	92
Faculty	15
Professionals	24
Institutions	7
Programs (e.g. enrichment)	6
Administrators	6
Parents	1
Departments	1
Classrooms	1
Companies	1

Note. Number does not add up to total count of 116 since there may be multiple objects of study per document.

Table 2.3
Characteristics by Field and Life Stage

Field	Undergraduate	Graduate	Career
Life Science	2	1	0
Physical Science	7	3	3
Mathematics	13	2	4
General Science	23	11	15
Computer Science/Technology	10	6	5
Engineering	19	12	20
STEM	19	5	4

Note. Life stage does not add up to total count of 116 since there may be more than one life stage per document.

Another notable point regarding the empirical documents on women of color in STEM is that many are recent: nearly half of the studies have been produced since 2000. Unfortunately, an attendant finding is that many authors, especially new scholars, such as authors of dissertations, are not publishing their findings.

Coding and Analysis

Team members developed codes using concepts identified in existing theory (Maxwell, 1996) and inductive categories using an “open-coding” technique (Strauss & Corbin, 1998; Glaser & Strauss, 1967). Taking a small but varied sample of the literature, the team tested codes, and then re-tested them, in teams of 2-3 members, for validity and inter-rater reliability. A codebook was developed and updated over several iterations, followed by the systematic coding of all documents. Coding and analysis of data were organized into three life stages: undergraduate, graduate, and career. Within each life stage is a series of top-level codes and sub-codes. For example, at the undergraduate life stage, top-level codes include student background characteristics and college experiences; sub-codes include socio-economic status and sense of belonging. (The section below on undergraduates is perhaps the most robust of the three life stages addressed in this synthesis, partly because of the comparatively large number of studies, but also because the coding and analysis revealed the depth with which scholars have addressed the external (e.g. racial climate) and internal (e.g. self-concept) dimensions of students’ lives.) In addition to the codes, the team paid attention to environmental contexts, such as institutional characteristics. These include, for example, minority serving institutions (MSIs), predominantly White institutions (PWIs), research-intensive universities, and those with highly selective admissions processes. The final codebook consisted of over 100 top-level codes and sub-codes.

The project team systematically tracked research methods (qualitative, quantitative, mixed methods) and research designs (e.g. quasi-experimental, experimental, interview study, ethnography, case study) used in each of the 116 empirical studies. See Table 2.4.

Table 2.4
Characteristics by Design and Method

Method	Design		
	Qualitative	Quantitative	Mixed Methods
Case Study	4	-	-
Ethnography	9	-	-
Interview Study	23	-	-
Phenomenological	3	-	-
Descriptive	-	21	-
Experimental	-	12	-
Quasi-experimental	-	34	-
Mixed Methods	-	-	10
Total	39	67	10

A full description of the project team’s searches, data collection, organization and storage methods, codes, analysis, and dissemination is provided in the project’s Technical Report (Wright and Ong, 2010).⁴

⁴ The report is available from the PI (Ong) upon request: mia_ong@terc.edu.

Limitations of the Study

The results from our project suggest that research on women of color in STEM is limited in number: our large-scale, systematic search covering 1970-2008 yielded only 116 empirical works. It should be noted that our searches were thorough but not exhaustive. The research field is further hampered by small sample sizes and lack of longitudinal analysis. In most cases, the in-depth studies tended to be qualitative. Furthermore, most of the existing research on women of color in STEM focuses on African American women. Very few studies explicitly address the experiences of women from Asian American, Chicana/Latina, and Native American backgrounds. Research on the career trajectories of women of color is further limited, as most studies exclude mid- and late-career experiences, particularly issues regarding tenure and promotion to full professor and leadership positions.

Another limitation of the study is that, due to constrained time, budget, and expertise, the project team did not conduct an assessment of the quality or the rigor of the studies. Therefore, the studies vary widely in terms, for example, of the number and strength of the methods applied, the quality of the writing, the quality of analyses, the numbers of participants in the study samples, and the page length of the reports. Moreover, several studies were not clear in their descriptions about whether the samples included non-U.S. citizens or non-U.S. permanent residents; we gave these studies the benefit of the doubt and included them in the synthesis, but we provide the reader with a caveat that for Asian/Asian American, African/African American, and Latina populations especially, citizenship status could critically affect their experiences in STEM. (Studies that clearly stated that their entire population samples were *not* U.S. citizens or permanent residents were excluded from the synthesis.)

On Terminology

We subscribe to the school of thought that claims that racial and ethnic (as well as gender) classifications are social, cultural, and political constructions (Brodin, 1998; Dominguez, 1986; Ong, 2005; Roediger, 1991; Warren, 2003; Waters, 1990). The meanings of such classifications are fluid, constantly changing, and negotiated throughout time; for example, a person who might identify, or be identified by others, as “Afro-American” in one instance may be “African American” in another and “mixed race” or “White” in still another (Dominguez, 1986; Hunter, 2002; Lawrence-Lightfoot, 1995). This recognition of the *construction* of race and ethnicity notwithstanding, the *effects* of race and ethnicity (and gender) differences are real, or at least perceived as real. Research therefore needs terms and labels to capture these classifications and resultant experiences in a given moment in time. Much of the literature included in this synthesis is from research studies that utilize pre-defined categories as conveyed in existing instruments, such as surveys.

The racial/ethnic terms utilized in this study often correspond to the categories used by data collection agencies (e.g., NSF, the U.S. Census Bureau, and the National Center for Education Statistics) and the authors whose works are included in the synthesis. The terms most

commonly used include: *African American*, *Black*, *Hispanic*, *Chicana*, *Latina*, *Native American*, and *Asian American*. For the purposes of this paper, the terms “Black” and “African American” are used interchangeably, as are “Hispanic” and “Chicana/Latina.” When specific authors use historically, regionally, or culturally specific ethnic or racial labels (e.g., Afro-American, Puerto Rican, American Indian), we include these terms in the descriptions of their work. Finally, the terms “women of color” and “minority women” are used interchangeably.

Why Include Asian American Women?

The inclusion of Asian American (and Pacific Islander) women in this synthesis study may be seen by some scholars as questionable, given their overrepresentation in scientific aspirations (see Chipman & Thomas, 1987; Staniec, 2004) and in STEM degree attainment (Chipman & Thomas, 1987; NSF, 2007). The perception that Asian American women are doing “fine” in STEM is further aided by the presence on campuses and in industry of a large numbers of foreign and international students and employees. There is often further conflation of Asian American and Pacific Islander subgroups that have strong representation in STEM (e.g., Chinese, Korean) with those that are not (e.g., Filipino, Vietnamese, Native Hawaiian) (Ong, 2005).

We contend that consideration of Asian American women’s status and experiences is important because despite their educational and early career successes, they, like other women of color, continue to be outsiders at the advanced levels of upper management and leadership in STEM academia, industry, and government (Burrelli, 2009; Wu & Jing, 2009). While Asian American women hold STEM doctorate degrees at a disproportionately higher rate than their respective U.S. population, they are the *lowest* represented demographic group with academic tenure (Burrelli, 2009), and they are nearly absent in full professor positions, particularly at the nation’s premier research universities (NSF, 2007; Nelson & Rogers, 2004) where, ironically, a critical mass of Asian American undergraduate and graduate students are in attendance.

SECTION THREE: THE UNDERGRADUATE EXPERIENCE OF WOMEN OF COLOR IN STEM

The talent pool for women of color in STEM has widened as demonstrated by an increase in this group’s overall representation in science and engineering baccalaureate degree attainment between 1994 and 2004 (NSF, 2009). However, a national 2006 review of population statistics and STEM baccalaureate degrees reveals differential attainment by URM women as compared to their White female peers (see Figure 1.1 on page 2). Further, despite outperforming their male peers in undergraduate math and science coursework (Grandy, 1998) and standardized test performance (Rodriguez, 1997), URM women nonetheless lag behind URM men in achieving bachelor’s degrees in several scientific fields including physics, computer science, and engineering (Mullen & Baker, 2008; NSF, 2007), and further experience these fields quite differently from URM men and White women (N.W. Brown, 1997; Varma & Hahn, 2007). Finally, women of all backgrounds are less likely than their male counterparts to persist past the baccalaureate STEM degree into graduate study and scientific careers (NRC, 2006).

A common argument to explain the underrepresentation of women of color in STEM is that this population is simply not interested in pursuing scientific degrees and subsequent careers. Debunking this line of thought is research that shows women of color as no less likely than White women to intend pursuit of an undergraduate STEM degree (Huang, Taddese, Walter, & Peng, 2000). Three prominent studies that specifically address the baccalaureate goals of African American women in STEM (Ethington & Wolfle, 1988; Hanson, 2004; Smyth & McArdle, 2004) revealed a far greater interest in scientific majors by this group when compared to their White female peers. This finding held true when examining women attending selective colleges and universities, as explicated by Smyth and McArdle’s (2004) finding that first-year African American women were more than three times as likely than first-year White women to intend pursuit of a degree in science, mathematics, or engineering. When compared to other women of color, a high percentage of Asian American women were also inclined to study STEM (Staniec, 2004; Chipman & Thomas, 1987), yet when measuring entry – as opposed to strictly interest – into a scientific major, Bonous-Hammarth (2000) found that Asian American women were still thirteen percentage points lower than their White female peers. These findings reveal a disturbing trend; despite great interest by women of color - particularly URM women – to pursue scientific majors, this group nonetheless remains underrepresented in STEM baccalaureate degree completion.

Many scholars (e.g., Hanson, 2004, p. 108) attribute this lost talent of women of color to educational and occupational institutions’ failure to fully develop science talent and point to the college social and structural environment as the main source for women of color’s attrition in undergraduate STEM education. This section specifically addresses the college experience of women of color in undergraduate STEM education through the synthesis of research on the social, academic, and structural environments of undergraduate institutions and the ways in which women of color navigate the STEM environment, including the importance of enrichment programs. The role of influential individuals and groups in women’s lives, faculty, peers, and family is further discussed. This myriad of forces in turn influences women’s identity and personal agency in pursuing a STEM degree, further shaping their view of what it means to pursue a scientific career.

The College Experience of Women of Color in STEM

The Racial/Ethnic and Gender Climate

Many of the studies that addressed the STEM climate in general, as well as the climate within departments and classrooms, discussed students’ navigation of majors and disciplines that have been historically – and currently – dominated by White, middle- and upper-class men. Several studies have specifically demonstrated and articulated the gender and racial/ethnic bias that women of color experience on a day-to-day basis as STEM majors, situating them in a unique position of confronting multiple systems of oppression. In Valenzuela’s (2006) qualitative study of Chicana/Latina students who had recently transferred from ethnically diverse community colleges to large research universities, those who took science courses that were overwhelmingly male, such as physics, experienced tension derived from their status as women, as well as their status as ethnic minorities.

Sosnowski (2002) presented similar findings in her phenomenological study of women of color in STEM at a predominantly White university. According to the author, “biased and stereotypical notions about race and gender often affect their classroom practices and create wounds to the self-esteem of students which are not so easily healed... moreover, they expressed the wounds created from teachers’ discriminatory biased attitudes and classroom practices” (p. 120). This last point of biased treatment by professors is particularly detrimental according to a conceptual model of identity development for women of color in STEM constructed by Carlone and Johnson (2007) that places recognition from others in a given STEM field as crucial to reinforcing the confidence women feel in pursuing scientific majors.

This recognition is hard fought given the dominant status of men in STEM fields. According to the authors:

In our science identity model, recognition was problematic for the women in this study because it hinged so crucially on an external audience. The composition of this audience, mostly White males, along with the institutional and historical meanings of being a scientist (being a White male), complicated their bids for recognition. (Carlone and Johnson, 2007, p. 1207)

Racialized treatment is equally damaging. The African American women in Justin-Johnson’s (2004) study “reflected on their persistence experiences by implicitly or explicitly expressing how issues of race determined the character of relationships with science faculty and students” (p. 152). Examples included being the only African American student in an upper-level science classroom and subsequent social isolation and pressure to perform in an effort to prove to the professor and their peers that she belonged there, both in the classroom and in the STEM major.

The culture of STEM majors is another important consideration, both in terms of the racial/ethnic and gender environment, as well as the other established elements of scientific fields. This includes a structure that is supposedly meritocratic in nature, with a focus on grades,

classroom performance, and research results that nevertheless ignores the social realities of racism and sexism in science environments (Carlone & Johnson, 2007; Varma, 2002). Ong’s (2002) six-year longitudinal study on women of color in physics concluded:

...young women of color in science have to carry out a tremendous amount of extra, and indeed, invisible work in order to gain acceptance from their male physics peers and faculty. These women must also pay more careful attention and learn to articulate for themselves the unspoken rules of membership in the physics culture, then learn creative ways to access and maintain this membership. In doing so, they come to understand and learn to negotiate the multiple aspects of the seeming invisibilities of science culture, whiteness, and gender. (p. 43).

This and several other studies addressed the nature of the lone woman of color in the science classroom or laboratory, heightened by the unwelcoming environment found in predominantly White science departments and campuses. This unsupportive climate can further lead to social stratification and low expectations of minority women (see Chinn, 1999).

A young woman in Dickey’s (1996) study who was the only minority woman in her laboratory said the following: “I’ve become more suspicious... I’ve just become aware that there are a lot of stereotypes, mostly negative, about women and Blacks that are internalized [by other students]” (p. 126). A participant in Varma, Prasad, and Kapur’s (2006) study of minority women in computer science and engineering majors explained her experience in the following way, “As far as being a woman, I don’t think they expect too many women to be in that area; as far as being a black woman, they don’t expect you to be there at all” (p. 310).

The racial climate for women of color is of further importance given its relationship to overall sense of belonging. Utilizing 2004 National Study of Living-Learning Programs data – which was comprised of responses from 1,722 women in STEM majors at 29 institutions – D. Johnson (2007) found a significant relationship between perceptions of a positive racial climate and overall sense of belonging for women identifying as African American, Asian Pacific American, and multiracial/multiethnic. A major finding in Justin-Johnson’s (2004) study of women of color in predominantly White science programs was the women’s perception of the “general campus climate for racial/ethnic diversity and its perceived impact on racial/cultural identity” (p. 122).

The African American women in this study pointed to the lack of African American peers in their science departments, as well as the segregated atmosphere of campus peer groups and the way in which the university promulgated this behavior by allowing such barriers to academic and social integration. On the contrary, there were findings that showed a supportive climate for women majoring in physics and engineering who attended Historically Black Colleges and Universities (HBCUs) (Lent, et al., 2005; Whitten, Foster, and Duncombe, 2003; Whitten et al., 2004). Key features of this environment were openness towards alternative routes into the major, a lack of stigma for remedial coursework, high expectations for student success, and a supportive and healthy relationship between students and faculty. Although several studies have examined predominantly White institutions (PWIs) and HBCUs, there is a dearth of literature on the distinct academic and social environments found at Hispanic Serving Institutions (HSIs) and

Tribal Colleges and Universities (TCUs) as it pertains to the collegiate experiences of women of color in STEM.

The STEM Classroom

Research has demonstrated that classroom experiences are critical to determining STEM persistence or attrition for all undergraduates. The literature on women of color furthers the argument by depicting the role of faculty, their pedagogical approach, and institutional type as interacting with other measures of climate; ultimately influencing the ways in which women of color approach valued classroom participation. In examining how faculty, pedagogy, and classroom climate at a predominantly White research university contributed to the discouragement of women of color to persist in science, A.C. Johnson (2007) found that women were less likely than men to raise questions in class.

Chicanas in Valenzuela’s (2006) study of math and science students at two predominantly White institutions (PWIs) were disappointed by the emphasis on lecture within the STEM classroom. This meant limited interaction with faculty, which extended to professors’ lack of accessibility outside of the classroom. Women of color further confront differences in classroom learning when moving from one institution to the next. Valenzuela (2006) studied Chicana/Latina mathematics and science majors who transferred from community colleges to large research universities. The most notable change for the students in their new institution was the shift in campus climate and classroom culture, or, simply said, their newfound sense of isolation. Valenzuela (2006) explained that community college classrooms were more racially/ethnically diverse and collaborative; in contrast, students experienced their new university classes as less diverse and lacking peer support due to emphasis on individualized learning, which was heightened by a competitive atmosphere.

The Role of STEM Enrichment Programs

Enrichment programs in STEM, specifically those that provide undergraduate research opportunities, have been shown to encourage STEM participation for all college populations, so it is of little surprise that women of color also benefit from their offerings. Aside from a nearly fifteen-year old NSF program at George Washington University that exclusively served women of color (Heller & Martin, 1994), research has focused on the benefits of STEM programs geared towards women and minority students as distinct populations. Perhaps most common were reports on the positive (as well as negative) experiences of women of color in undergraduate research assistant positions (Dickey, 1996; Johnson, 2006). Minority women often experienced their laboratories and research groups as the only researcher of their gender and race/ethnicity (Johnson, 2006; Ortiz, 1983). Still, these programs provided opportunities for women to be mentored, and in some cases, faculty played a positive role in influencing minority women in their careers (Dickey, 1996; Ellington, 2006; Schimmel, 2000). Indeed, Espinosa’s (2009) study showed undergraduate research program experience as positively related to overall persistence in STEM majors.

When considering STEM retention programs, overall – those with and without research components – there was general agreement on their positive impact along multiple dimensions of

student experience. In her ethnographic study of women of color in physics at a predominantly White research institution, Ong (2002, 2005) learned that recruitment and retention programs that chiefly served women or minorities in physics provided critical safe spaces for women of color to belong to a supportive community of scholars who looked like them, to reject negative stereotypes and validate their identities as emergent scientists, to learn how to address “microaggressions” (subtle offenses) from faculty and peers, and to grow their sub-community by serving as role models, mentors, and teachers (p. 115-116).

Nave, Frizell, Obiomon, Cui, and Perkins (2006) examined the performance and graduation rates of women who were part of the National Science Foundation sponsored STEM-Enrichment Program (STEM-EP) at a historically Black university. They found that this group outperformed their male peers. At another type of institution, community colleges, Chicana and Latina women found academic, personal, and social support from the Mathematics, Engineering, Science, Achievement (MESA) program; this was an experience these students recognized as critical to their success in STEM, their aspirations, and their subsequent transfer to four-year research universities (Valenzuela, 2006).

The high academic expectations set forth by retention programs and program staff were also critical in supporting student persistence (Ellington, 2006), as was the cohesive peer community for minority scientists that these programs foster (A. Johnson, 2005). S.W. Brown’s (2000, 2002) qualitative study on the educational journeys of 22 Hispanic women scientists illustrated the importance of formal science programs in instilling confidence in the women that they were worthy and capable of success. Ellington (2006) and Meiners and Fuller (2004) attributed student success to the ease of formation of study groups and inherent peer support provided by STEM retention programs.

Relationships and Influences

Research suggests that women of color seek out academic and personal support vigorously and with serious intent to bolster their confidence in STEM majors and subsequent determination to graduate. Women of color tap a host of networks that include parents, faculty members, university administrators, and peers in and outside of STEM. The African American engineers in Shain’s (2002) study cultivated “strong social networks of peers, minority administrators, faculty members, and minority engineers that contributed to their sustainability in engineering” (p. 165). Similarly, the African American mathematics upperclasswomen in Ellington’s (2006) study were greatly supported by their parents, teachers, and peers. Further, Chicana/Latina transfer students attending predominantly White research institutions and majoring in STEM disciplines (Valenzuela, 2006) utilized their social capital – by seeking out tutoring, student groups, and other campus resources – to create support systems that helped them succeed as young scientists in an otherwise typically unfriendly environment for women and students of color. Indeed, Fuller and Meiners (2005) found that women of color value university settings where they can contribute to the community at large, this activity itself providing support and encouragement to succeed.

Interestingly, among the various sources of support people young women of color tapped into, it was not necessarily the case that role models and peers were of shared gender and

racial/ethnic backgrounds. Perhaps given the overwhelmingly male-dominant atmosphere of engineering majors, the African American women in Shain’s (2002) study indicated that while their cultural and racial identity was important to their educational experience overall, the gender of their support person in the major was not vital to the completion of their degree. According to Shain:

Although the women were aware of the male dominance in engineering schools, overall, the women seemed more concerned about learning and understanding engineering facts than being able to identify with someone like themselves. It appeared the women were able to segment the levels of support to fit their academic or social needs. (p. 161)

This is a good example of how women of color make personal adjustments to suit the culture of their chosen discipline, such as seeking mentors outside their gender and/or racial group for the simple fact that there is a lack of role models that share their background and educational experience (Ellington, 2006; Justin-Johnson, 2004).

Faculty Relationships

The literature presented a mixed review of student-faculty relationships. For some women of color, their gender, race, and ethnicity were seen as major barriers to being perceived by professors as serious students (Carlone & Johnson, 2007; Wightman Brown, 2000). For other women, professors played a critical role in making a STEM career a reality (Ellington, 2006; Whitten et al., 2004). In the case of Johnson’s (2006) study, given the sheer importance that women of color placed on relationships, they found themselves discouraged by – and unsatisfied with – faculty who focused their attention on relaying their subject matter of expertise, rather than creating interpersonal connections with the students in their classrooms. Women of color in Espinosa’s (2009) dissertation study who switched out of STEM had more interaction with professors than women who stayed in these majors as evidenced by a negative relationship between faculty interaction and four-year STEM persistence.

On the contrary, Ellington (2006) and Dickey (1996) reported a positive finding of women of color viewing professors as instrumental in making a STEM career a real possibility. The former study reported students attending these institutions as having positive faculty interactions, a finding supported by Whitten et al. (2004) in their research on the success of women studying physics at HBCUs. Positive and influential student-faculty experiences are further seen in research mentor relationships, a finding that has been reported in numerous studies of underrepresented students in science (Alfred, et al., 2005; NRC, 2006; Schimmel, 2000).

Peer Relationships

Peer support networks emerged as critical in long-term student success, particularly given the way that women of color were challenged in finding other students with similar academic experiences and backgrounds within their majors. Studies underscored the importance of peer group interaction and mentoring (Espinosa, 2009; Guevera, 2007; Hall, 1981), but also touched

upon students' inability to infiltrate peer study groups that did not include other minority women (Justin-Johnson, 2004) and the social distance that occurred as a result of the lack of students with whom to identify (Tate & Linn, 2005). In response, students often turned outside of STEM but within their racial or ethnic community. Shain (2002) reported that the African American women in her study “frequently reported feeling alienated in the engineering school environment and usually found comfort in their cultural groups” (p. 170). In a study of high-ability minority science students, Grandy (1998) found that the women in her sample embodied strong social development, including participation in campus organizations and leadership experiences.

Tate and Linn (2005) found that women of color engineering majors socially aligned themselves with peers depending on an academic versus non-academic context. That is, when socializing with students within their major, women tended to spend time with students from the major ethnicities represented in the overall engineering population, namely Whites and Asians. On the contrary, when seeking social interaction not affiliated with academics, women socialized predominantly with students of their respective ethnicities. Academic and non-academic social peer groups further differed by academic focus. Academic groups tended to be composed of engineering majors, while social groups were typically composed of non-engineers. Because of this difference, the students interviewed reported that social identity within an academic context was often characterized by a lack of belonging. Conversely, the ethnicity-centered nature of social peer groups did not produce this same distance.

Family and Community

Family and community support was perhaps the most salient and influential finding when it came to how women of color perceived those elements of their life as most encouraging to their completion of a STEM degree (Andrade, 2007; Bellisari, 1991; S.W. Brown, 2000; Carlone & Johnson, 2007; Ellington, 2006; Grandy, 1998; Russell & Atwater, 2005). Russell and Atwater's (2005) research identified three key tenets of parental influence for the African American science women in their study, namely, the role of parental encouragement, acceptance, and educational expectations (p. 707). There was further emphasis on the role of women's mothers in providing ongoing support from the early years through postsecondary education (Ellington, 2006; Hanson, 2004, 2006; Maple & Stage, 1991; Shain, 2002; Sosnowski, 2002; Valenzuela, 2006). These ties can be seen as a driving force for women, although the degree to which family and community influence enters their lives varies by individual and in some respects, by cultural background (Brown & Cross, 1997; Trenor, et al., 2008) and parental education level (Trenor, et al., 2008).

The support that family provides, however, can also be seen as a force that pulls women away from STEM. Some students found that their families questioned their long-term goals of becoming a scientist while also facing pressure to contribute to the family financially, to provide child care, and/or to uphold traditional female ideals of marrying and raising a family. These findings seemed particularly salient for students from Chicana/Latina backgrounds (Valenzuela, 2006). Native American women in Varma and Galindo-Sanchez's (2006) study were expected by their families to manage the family structure, including the large external family. African American women in Chowdury and Chowdury's (2007) study reported an absence of support from family to study engineering as a negative force in engineering enrollment. Parental pressure

was found to promote negative associations with one’s major choice, as well. Asian American women in science majors reported feeling restricted in their career choices due to parental expectations (Schimmel, 2000), especially as it had to do with choosing majors that their parents saw as an acceptable route to long-term career success (Bellisari, 1991).

Carlone and Johnson’s (2007) science identity model for women of color stressed the importance of recognition by others as meaningful in women’s lives. These “others” could be those in the scientific community, but for some women, their family and community played a dominant role in how they saw and pushed themselves to succeed. One of the women in the study stated:

We have the pressure from our communities, so it’s really hard for me to go home with bad grades. And that’s the pressure people of color have, is we have to bring something back to our community that will be helpful... They’re watching us. We have that pressure to do well. And that’s a good pressure. (Carlone & Johnson, 2007, p. 1201)

This feeling of obligation to represent one’s community by succeeding in STEM (Ellington, 2006; Shain, 2002) continues to present itself through the ways in which students identify as women, as women of color, and as people from underrepresented racial or ethnic communities. Given the emphasis on family support explicated in these studies, it is important for scholars to further address the nature of family in women’s lives from a non-traditional perspective (e.g. students from single parent households, with families of their own, and/or in non-heterosexual families and partnerships).

Academic Sense of Self

Much of the literature on the ways in which women construct their identity as STEM majors is centered on academic self-concept, self-efficacy, and overall confidence in one’s academic abilities. Several studies measured the confidence women felt in their abilities, including how confidence was lower for women of color and how this construct was developed over the four years of college. Utilizing two self-efficacy scales to explore how Hispanic women and men compared in math confidence levels, Brownlee (2004) found the women in her study as less confident in their ability to perform in math courses when compared to their male counterparts. Minority women in STEM have been further shown to lose math confidence during college (Espinosa, 2008) and to have lower levels of math self-efficacy at college entry and subsequent time points when compared to male peers (Lopez, Giguette, & Schulte, 2006).

In a quantitative survey study of 228 Asian American undergraduates majoring in STEM at a large research institution, Vogt (2005) utilized path analysis to examine background and college environment influences on self-efficacy and academic performance. Her study found a mediating effect of self-efficacy between environmental influences and academic achievement, as well as a strong link between collegiate peer support and high school grades on students’ educational sense of self. In Espinosa’s (2008) work assessing the development of academic self-concept during the undergraduate years, minority women placed importance on working on group projects in class, tutoring another student, and having high academic expectations of themselves at college entry.

Self-efficacy and academic confidence has further been explored in relation to STEM entry. A strong relationship was determined to exist between science self-efficacy and the choice of a scientific major for African American women (Gwilliam & Betz, 2001). Maple and Stage (1991) found that the attitudes African American women held towards their math ability directly impacted STEM major choice. Beyond STEM entry, self-confidence has been shown to be an important factor in the academic success – and constant need for adjustment to the rigors of the engineering environment – of African American female engineering majors (Shain, 2002).

Personal Agency and Drive

The personal agency and drive of women of color has been shown to develop and greatly unfold during the undergraduate years (Ellington, 2006). Varma (2002) found that the Hispanic females in her study of computer science/engineering women attending an MSI were often determined to achieve their bachelor’s degree by way of personal drive. African American women in Ellington’s (2006) study expressed their persistence in math as having to do with personal interests and agency. Valenzuela (2006), too, found an incredible force of personal strength, confidence, and competence in the success of Chicana and Latina transfer students in science and math. The author termed this strength “mi fuerza” or “inner fire to succeed” (p. 88).

Part of this inner fire has to do with the way in which students tap into their racial and cultural identities. Despite marginalization, women of color often use their status as a member of two underrepresented groups – as a women and a person of color – to empower themselves (Carlone & Johnson, 2007; Ellington, 2006; Ong, 2002, 2005), tying directly to the way in which students understand and handle racism and the subsequent ability to navigate the STEM environment (Shain, 2002). Women of color can be seen as embracing their cultural difference and using it as a vehicle for success (Sosnowski, 2002). Hanson (2004) pointed to the construction of gender in the African American community as being congruent – and not at odds – with personal characteristics needed for success in science: high self-esteem, independence, assertiveness, and high educational and occupational goals.

Yet, tapping into one’s cultural identity can further sensitize women of color to gender disparities. Utilizing Steele and Aronson’s (1995) stereotype threat theory (that negative stereotypes undermine performance by groups embodying a particular socially constructed stereotype), Gonzales, Blanton, and Williams (2002) found that the ethnic identity of Latina women sensitized this group to negative stereotypes about their gender, leading to poor mathematical and spatial ability test performance when stereotype threat was activated. Cheryan and Bodenhausen (2000) tested the hypothesis that positive stereotypes can also hinder performance by creating pressure to live up to the high expectations associated with said stereotype. The researchers conducted the experiment with Asian American women who placed personal importance on their mathematics ability and ran a negative gender-related stereotype (women are bad at math) as well as a positive ethnic-related dimension (Asians are good at math). While the Asian American women did not respond to the study’s gender-related threat construct, they did respond to the ethnic-related threat, signaling that positive stereotypes can indeed constitute a threat to performance.

Perceptions of STEM

Research on women in science and engineering has often explored the role of long-term family goals, the nature of scientific inquiry, and the benefits and deficits of contributing to the scientific community as reasons women leave STEM disciplines. Research on women of color, too, has begun to address these issues. Interview data collected by Grandy (1998) led the author to conclude that minority women in the sciences experience a “conflict between their passion for science and their desire to have a family, believing that a science career is too demanding and will not allow them sufficient time with family” (p. 611). Women of color in Schimmel’s (2000) study experienced career conflict as early as their first year, leading them to switch out of scientific majors.

Some researchers found gender differences among students who pursued science careers. The women in Grandy’s (1998) study of high-achieving minority science students had less of a desire to pursue science than their male peers. According to the author, “Making the kinds of contributions and discoveries that scientists and engineers make was somewhat less important to female than male students” (p. 602). It may be that some women identify only with certain types of contributions, like those that have real-world humanitarian value. In Carlone and Johnson’s (2007) study, the women who aspired to become scientists and were on what the authors refer to as a “research science trajectory” (p. 1197) were specifically interested in science for science’s sake. This study identified another set of women of color on a science trajectory that was altruistic in nature. In reference to these women, the authors stated, “their reasons for pursuing science, then, were less about science itself and more about science as a vehicle for altruistic ambitions” (p. 1199). Johnson (2005) found something similar in the way women had a desire to help others, while A.C. Johnson (2007) specifically addressed this desire of the women in her study to enter the health professions and use their scientific talent to serve the community. One cannot underestimate the need to understand why women of color choose STEM majors and continue through the baccalaureate given the decrease in representation of enrollment at the graduate level and the importance of understanding the STEM graduate school experience.

SECTION FOUR: THE GRADUATE EXPERIENCE OF WOMEN OF COLOR IN STEM

S.V. Brown (2000) identified the transition from college to graduate school as a “strategic point of loss” for minority students in STEM (p. 247). It is especially a loss of minority women. Women of color are growing in numbers on campuses, and they are earning more bachelor’s degrees relative to their male counterparts in almost every STEM discipline; therefore, they have the requisite degree for entrance to graduate school. However, they earn fewer Ph.D.s relative to their minority male peers as well as to their White male and female counterparts (NSF, 2007). It is therefore critical to consider women of color as a great, untapped resource that could assume highly ranked professional positions in STEM industry and government. Moreover, all women of color, including Asian Americans, are severely underrepresented as STEM faculty, particularly at the associate and full professor ranks (NSF, 2007; Nelson & Rogers, 2004). Because faculty hires are usually selected from newly produced Ph.D.s, recruiting and retaining women of color in graduate school is paramount for diversifying the nation’s faculty.

Several scholars (e.g., S.V. Brown, 1995, 2000; Erickson, 2007; Hall, 1981; Malcom, Hall, & Brown, 1976; Ong, 2002, 2005) have argued that the informal, non-academic elements of graduate STEM programs hinder women and minorities more than any other component of the graduate school experience. Graduate education, particularly in STEM programs, is a largely informal process (Fox, 1995). As such, STEM graduate education is often fraught with challenges such as finding a supportive mentor, learning how to navigate departmental and laboratory cultures, building professional and social networks, finding funding to support one’s education, learning how to write research grant applications, and gaining access to the professional circuit through activities such as research, publishing, and giving conference presentations (Nettles, 1990; Traweek, 1988). How well these challenges are met can play a determining role in students’ options and choices for postdoctoral programs as well as their subsequent career choices (MacLachlan, 2006). While the informal process introduces challenges for *all* students, because many of the activities require social interactions and/or interpersonal relationships, they can present particular difficulties for non-traditional students such as women of color. To give two broad examples, several studies described below cite that women of color graduate students report a sense of isolation in the departmental community and feel that professors and peers doubt their academic abilities. These experiences can deeply hinder attempts to join study groups or develop good relationships with potential mentors.

This Section is organized into two parts. The first part synthesizes four prominent studies that examine the parity status of different groups of women of color in graduate school. It also highlights findings on the baccalaureate origins of Chicana doctoral recipients in STEM between 1980 and 1990 and of African American female doctoral recipients in STEM between 1975 and 1992. The second part offers a synthesis of findings on the graduate school experiences of women of color in STEM. Subsections discuss academic preparation and transitions from college, family influence and support, funding, social climate, mentoring and role models, faculty influence and support, outreach, and graduate training.

Graduate-Level Parity Status and Baccalaureate Origins of Women of Color in STEM Graduate Programs

Doctoral Parity Status and Baccalaureate Origins of Chicana Ph.D. Students

Solórzano (1995a) conducted secondary analysis of quantitative data from the National Research Council’s (NRC) Doctorate Records Project (DRP), focusing on the baccalaureate origins of Chicana and Chicano Ph.D. recipients between 1980 and 1990 in the general fields of physical, life, and engineering sciences.⁵ Solórzano found that, in comparison to the percentage of their national 30-34 age cohort (4.5%), Chicanas were severely underrepresented in physical, life, and engineering sciences. Further, compared to Chicanos, Chicanas were underrepresented in each of the three broad science and engineering fields. Solórzano concluded that it would take a tremendous increase in production – “anywhere from 6- to 17-fold” (1995a, p. 259) for Chicanas to reach parity with their overall U.S. population in these three scientific fields.

Between 1980 and 1990, 101 Chicanas received doctorates in the fields of physical science, engineering, and life sciences (Solórzano, 1995a, p. 262). (Chicanos received 294 doctorates in these fields during the same time period (Solórzano, 1995a, p. 25).) Solórzano reported that between 1980 and 1990, only nine institutions produced three or more Chicana baccalaureate recipients who went on to receive doctorates in physical, life, or engineering sciences, and that these schools were concentrated in Texas, New Mexico, Arizona, and Southern California. He noted that two Hispanic-Serving Institutions (HSIs), Our Lady of the Lake and the University of Texas, El Paso, produced 20% of Chicanas who continued on to receive science doctorates. Overall, however, Chicana science doctorates were less inclined to begin their educational careers at HSIs. Instead, Solórzano reported, they tended to attend large, comprehensive research universities (p. 266), perhaps due to the relative prestige and reputation of the latter in producing science doctorates. Burrelli’s (2009) more recent findings reveal a different trend: Between 2003 and 2007, among the five highest producers of Hispanic female STEM bachelor’s degree recipients, four – University of Puerto Rico Mayaguez, University of Puerto Rico Rio Piedras, Florida International University, and California State University Northridge – are Hispanic-serving institutions. The one exception, University of California, Los Angeles, currently with 15% Hispanic student enrollment, was recently identified as an “emerging HSI” by Excelencia in Education, a Latino advocacy group (Moltz, 2010).

We did not find any empirical work on the master’s parity status for Chicanas for any year between 1970 and 2008. We also did not find any empirical work on the doctoral parity status or baccalaureate origins (including community college origins) of Chicana doctorates that addressed the years prior to 1980 or after 1990.

⁵ Determining that the average STEM Ph.D. graduate was 32 years old, the author developed and applied a “Doctoral Parity Index” which he defined as “the percent of Chicana/o PhDs for the period from 1980 to 1990 divided by their average percentage of the population age 30-34 from 1980 to 1990 (i.e., 4.5% for [Chicana] females)” (Solórzano, 1995a, p. 258). In other words, 1.00 would indicate parity; a number over 1.00 would indicate overrepresentation, and a number under 1.00 would indicate underrepresentation.

Doctoral Parity Status and Baccalaureate Origins of African American Ph.D. Students

Solórzano (1995b) conducted a similar secondary analysis using quantitative data from NRC’s DRP to determine the baccalaureate origins of African American doctoral students between 1980 and 1990. Using the same Doctoral Parity Index (see Footnote 1), he determined that African American females were severely underrepresented in the sciences and engineering: to reach parity with their cohort representation, there would need to be doctorate production increases from 500% to 1100% in certain disciplinary fields. Compared to African American women, African American men were concentrated in higher numbers in engineering and the physical sciences. During the 11-year period of 1980-1990, there were a total of 547 African American women who received doctorates in science and engineering (Solórzano, 1995b, p. 20). (African American men received 1,154 doctorates in science and engineering fields during the same time period (Solórzano, 1995b, p. 20).) Solórzano (1995b) reported that 30 out of the top 50 undergraduate institutions that produced African American female doctoral recipients in science and engineering were Historically Black Colleges and Universities (HBCUs). Furthermore, when school size of the top 50 producers was controlled, the authored deemed small colleges to be more productive than large schools in producing African American doctorate recipients.

Leggon and Pearson (1997) studied an NRC dataset for African American science doctoral recipients over a greater time period, and while their findings resonated with Solórzano’s (1995b), their analysis included a closer examination of the effects of HBCUs, small institutions, and women’s colleges. Leggon and Pearson conducted a secondary analysis of NRC data on the baccalaureate origins of 1,465 African American female Ph.D. recipients in the general fields of biological sciences, physical sciences, and social sciences who received their degrees between 1975 and 1992. They found that among those earning biological science Ph.D.s, 73% had earned baccalaureate degrees at HBCUs. Among those earning physical science Ph.D.s, 68% received baccalaureate degrees at HBCUs. The authors found that women’s colleges were critical for producing students who went on to get Ph.D.s: among those schools considered in the study (which had two or more graduates in the 18-year period considered), there were 27 African American women in the biological sciences, and six in the physical sciences, who went on to get Ph.D.s subsequent to attending women’s colleges. Two women’s colleges that primarily serve African Americans – Spelman and Bennett – were especially effective: 18 of the 27 women in the biological sciences and four of the six in the physical sciences had come from these two schools. The authors concluded that HBCUs and women’s colleges produced a disproportionate number of African American female Ph.D.s in science because of deliberate infrastructure to recruit and retain students in these fields; infrastructure included supportive faculty, strong sense of community, curricula that encouraged collaboration and real-world applications, and programs designed to promote success.

We did not find any empirical work on the master’s parity status for African Americans for any year since 1970. We further failed to find any empirical research on the doctoral parity status or baccalaureate origins (including community college origins) of African American female doctorates that addressed the years 1970-1974 or 1996 to the present. However, a recent NSF (Burelli & Rapoport, 2008, p. 3) report showed that among African American science and

engineering doctorate recipients, the top five baccalaureate-origin institutions for years 1997-2006 were HBCUs: Howard University, Spelman College, Hampton University, Florida A&M University, and Morehouse College. However, over the last two decades (1986-2006), non-HBCUs have produced as many or more future African American science and engineering doctorates relative to HBCUs. The report states, “when data from 1986 to 2006 are normalized by the number of bachelor’s degrees awarded, HBCUs as a group yielded about as many future S&E doctorates per thousand bachelor’s awarded as non-HBCU institutions during this period” (Burelli and Rapoport, 2008, p. 3). Notably, after normalizing for the number of bachelor’s degrees awarded, Spelman College was the only HBCU in the top 25 (Burelli & Rapoport, 2008, p. 4).

Master’s and Doctoral Parity Status and Baccalaureate Origins of Native American, Chicana/Latina, and Asian American Female Graduate Students

Compared to the rich, historical reports on Chicana and African American women provided by Solórzano (1995a, 1995b) and Leggon and Pearson (1997), very little information exists about the parity status or baccalaureate origins of Native American, Chicana/Latina, and Asian American female graduate students. Chipman and Thomas (1987) gave a snapshot of these groups’ parity status, or what they call “representation ratios,” using U.S. Office of Civil Rights data on master’s and doctoral degrees awarded in 1976 to male and female racial/ethnic minority groups in the areas of biological science, computer and information science, engineering, mathematics, and physical science.

Chipman and Thomas (1987) calculated the representation ratios “by dividing the percentage of degree recipients that belong to a particular group by the estimated percentage of the total U.S. population belonging to that group” (p. 390). The authors determined that in STEM, Native American women were represented at the master’s level at around 63% (or .63) of their representation in the population as a whole (men were .40). At the Ph.D. level, Native American men were better represented than Native American women (.40 vs. .27). However, the authors warned, “the small size of the populations and the ambiguity of group membership make it difficult to be as certain of one’s statistics” (p. 390). For Hispanic groups, the representation ratio in STEM at the master’s level was .34 for both men and women, but at the Ph.D. level, Hispanic men were better represented with a ratio of .25, as opposed to .16 for Hispanic women. For Asian Americans, the representation ratio in STEM was calculated at 1.13 for women and 1.86 for men at the master’s level, indicating overrepresentation in STEM for both groups relative to their respective U.S. population. However, at the doctoral level, the ratios were .88 for Asian American women and 3.29 for Asian American men at the Ph.D. level. The authors state that the numbers for this group may have been inflated since they could not distinguish between native-born and foreign-born Asians.

Chipman and Thomas (1987) concluded that the “depressed rate of participation of women at the most advanced levels of education has occurred within each of the minority groups, as well as within the white majority” (p. 391). As changes in participation in STEM by women of color (and men) have occurred over the last three decades, there is a need for scholars to conduct new parity studies. No empirical work was found regarding the baccalaureate origins,

including community college origins, of Native American, (non-Chicana) Hispanic, or Asian American women of color who have pursued Ph.D.s in STEM fields.

The Graduate Experiences of Women of Color in STEM

Academic Preparation and Transition from Undergraduate STEM Majors to Graduate STEM Programs

Academic preparation is a serious component for success in graduate school for any student, but it carries particular significance for women of color entering STEM graduate programs. Yet, a sizeable number of Chicanas/Latinas and African American women have been trained at minority-serving institutions (MSIs), which are generally perceived as less prestigious schools and have less infrastructural support in STEM, such as cutting edge scientific equipment (Leggon, 2001; Leggon & Pearson, 1997; MacLachlan, 2006; Solórzano 1995a, 1995b;). Small institutions, especially women’s colleges, are also strong undergraduate producers of women of color who pursue Ph.D.s in STEM (Solórzano 1995a, 1995b; Leggon & Pearson, 1997). Because of the focus on teaching at these schools, however, these institutions often lack updated research facilities and strong research programs where undergraduates can receive laboratory training. As a result, graduates from MSIs, small schools, and women’s colleges often arrive at their STEM graduate programs underprepared relative to their counterparts from predominantly White and/or large research universities.

Joseph (2007) conducted an ethnographic study of six African American first- and second-year female graduate students in mathematics and chemistry programs at predominantly White institutions (PWIs) who had baccalaureate origins in HBCUs. According to the author (2007), while at their HBCUs, the students worked hard, received strong support from their professors, and earned good grades. As such, most of them were taken by surprise when, upon entering their graduate programs, they suddenly had academic difficulties, which were then compounded by social challenges:

They did not know that the lack of advanced courses, the lack of sophisticated equipment at their undergraduate institution, their gender and the color of their skin would place them in a precarious spot in graduate school. (p. 195)

MacLachlan (2006) conducted an interview study that included 35 women of color scientists who received their Ph.D.s from the University of California. Similar to Joseph (2007), she found that a subset of African American women in the study who attended HBCUs had difficulties in their transition to PWIs (p. 239).

Concentrating on the Midwest region of the country, Santiago and Einarson (1998) studied graduate students participating in the longitudinal Graduate Experience Project, which focused on students’ experiences in physical science and engineering programs. Their quantitative survey study included 290 participants, including male and female U.S.- and foreign-born graduate students. Examining performance on the verbal and analytic portions of the Graduate Record Examination (GRE), the authors said, “Significant group differences were noted in terms of performance on the GRE, with U.S. minority women at a particular

disadvantage relative to their nonminority peers” (Santiago and Einarson, 1998, p. 173). Nevertheless, survey results did not reveal any significant differences between the demographic groups in reported self-confidence or self-efficacy. In fact, 43% of minority women felt their gender to be an asset (compared to 60% of White women), and over half of the minority women reported that their race/ethnicity was an asset.

In a 1978 national survey study of 52 minority women STEM professionals who were members of the National Network of Minority Women in Science (MWIS), respondents recommended providing better undergraduate training, facilitating student memberships to undergraduate honor societies, providing information about graduate departments, and enacting more aggressive efforts to identify and enroll minority students (Hall, 1981, p. 14). These actions, the respondents anticipated, would help women of color’s academic preparation and transition to graduate school, and would therefore retain their participation in STEM. Hall’s (1981) survey report, like the other literature in this section, seems to acknowledge the finding that women of color do not receive equitable undergraduate education or other preparation (e.g., research experiences) for graduate school compared to their minority male or nonminority counterparts. Clearly, there is a disconnect between undergraduate environments where women of color seem to thrive in STEM—HBCUs, women’s colleges, small colleges, and less prestigious institutions— and the graduate programs that receive them.

Family Influence and Support

A few empirical works on women of color graduate students in STEM cited the importance of family influence and support. The minority women in MacLachlan’s (2006) study generally “enjoyed very strong support systems provided by their families, including parents with virtually no education who sustained them through school” (p. 239). Hanson (1996, 2004) conducted a longitudinal study of three large data sets (High School and Beyond, LSAY, and NELS), reporting a notable finding that African American women have the advantage, relative to their non-African American counterparts, of family resources, especially their mothers, to promote their careers in STEM. Her research found that African American mothers were more likely to work as their daughters were growing up, and thus conjectured that they served as strong role models and provided the young women with “more liberal sex-role attitudes” that encouraged them to pursue studies and careers in the non-traditional fields of STEM (p. 163). In Sosnowski’s (2002) phenomenological study, an African American female engineering doctoral student credited the support and strength of her family, especially her mother, for the simple life they lived in while growing up in the segregated South. The principles she learned in a strong, religious family, Sosnowski argued, gave the student the emotional tools “she would need in her struggle in a male dominated field while being a single mother and caring for her son in the pursuit of her engineering degrees” (p. 91).

Funding Issues

Paying for costs associated with graduate education (e.g., tuition, textbooks) as well as costs of living while in graduate school (e.g., housing, meals, and, in some cases, child care), are important factors in recruiting and retaining students in STEM. When Hall (1981) asked professional minority women in STEM (all members of MWIS) in a survey what they would

recommend to retain young women of color in graduate STEM programs, by far the most popular response was financial aid, including grants, loans, and fellowships. Sosnowski (2002) wrote, “There is a lot of money out there for minority students in SMET [science, math, engineering and technology]. Finding access to and negotiating the requirements and paperwork is often a major stumbling block to fund the cost of tuition and maintaining enrollment in an engineering program” (p. 64). The author illustrated her point with her description of Grace, an African American woman in a Ph.D. engineering program, who had relied on getting an NSF fellowship but found out just prior to enrolling that she did not receive it. In order to pay for tuition, fees, and other costs of graduate school, Grace had to dip into retirement savings from a previous job. Sosnowski (2002) and others (e.g., Hall, 1981) recommended that undergraduate and graduate programs make transparent the availability of funds for graduate school and provide guidance in navigating the processes of applying for these funds.

While fellowships and other funding are important in promoting graduate study in STEM, one quantitative study suggested that women of color were at a disadvantage in obtaining a prestigious national award. S.V. Brown (1995) studied the patterns of faculty and research scientist scores given to applicants for the NSF Fellowships. Applying a regression analysis that correlated faculty/scientist scores with gender and race/ethnicity of applicants, she found that being a minority woman:

reduced the chances of winning a fellowship as applicants moved from one decision-making point to the next. For example, minority women are significantly less likely to receive high panel rating averages, to be placed in the top two quality groups (from which awardees are selected), or to receive offers of fellowships. (p. 259; see also S.V. Brown, 1995)

Perhaps even more discouraging, S.V. Brown (2000) found that minority women were “significantly less likely to attain the doctorate irrespective of whether or not they received an NSF fellowship” (p. 259). These findings held even when the program, field of study, GRE scores, and undergraduate grade point averages were taken into account. Indeed, S.V. Brown’s (1995, 2000) findings suggest that factors beyond high ability and financial support negatively affect women of color graduate students in STEM.

Social Climate

Our synthesis study found that the majority of empirical research on the graduate experiences of women of color in STEM presented findings on social climate. As noted above, even when factors such as financial aid and academic ability were accounted for, women of color were more likely than their male minority and White classmates to drop out of their graduate programs (S.V. Brown, 2000). A large survey study of minority women in STEM graduate programs conducted by S.V. Brown (1994, 2000) revealed that “interpersonal relations” (S.V. Brown, 2000, p. 258) caused more difficulty for the women of color than even structural barriers such as financial aid, recruitment practices, composition of the faculty body, tutorial and counseling support, and teaching or research assistantships. The author found that problems regarding social climate/interpersonal relations included isolation, racism, sexism, being racially/ethnically identifiable, and relationships with faculty and other peers. (Minority

women’s interactions with faculty are discussed in a separate section, “Faculty Influences and Support”.)

A few studies stated that lack of community with peers in one’s academic department, and, sometimes, outright mistreatment by peers, had negative effects on women of color’s experiences in graduate school. In her survey study, S.V. Brown (2000) found that “White students were often described as arrogant and indifferent, while minority men were said to treat minority women as intellectual inferiors” (p. 259). MacLachlan (2006) reported that in her study, minority women felt surveilled by their peers and that “problems with racism and sexism tended to originate with male student colleagues” (p. 241). As a result of their social isolation and perceived inferiority, these women of color had few opportunities to form study groups with their peers, a strategy widely regarded as key for succeeding in graduate programs (S.V. Brown, 2000).

Joseph (2007) conducted an ethnography and interview study on six African American women at the beginning of their graduate careers at PWIs. She found that the students in her study, who were often the singular African American woman in their respective mathematics or science Ph.D. programs, felt socially isolated and without community in their departments. In stark contrast to their undergraduate years at HBCUs, which were mostly “filled with encouragement and support” (p. 194), Joseph (2007) stated that in their predominantly White graduate programs, “Meeting people and finding their place in the department was difficult. It took a great deal of time and effort for them to get to know people” (p. 195). One chemistry graduate student the author interviewed said, “I feel most of the time that I am so different from everyone here and really alone” (Victoria, quoted in Joseph, 2007, p. 116).

To cope with being the only African American female in their cohorts in their respective Ph.D. programs, the students in Joseph’s study often employed a strategy of *fragmentation* (Lugones, 1994; Ong, 2002, 2005). Fragmentation is a strategy that entails actively separating parts of one’s identity, foregrounding one part while playing down another in a particular context. In the case of the women Joseph studied, they focused on disciplinary work while at school but nurtured their social identities elsewhere. For example, a mathematics graduate student reported that, while at school, “I have forced and convinced myself to be successful and changed my mode of thinking and concentrate on math and math only” (Kerry, quoted in Joseph, 2007, p. 91). Another student said, “I do not reveal everything about myself to those I associate with in the chemistry department at graduate school” (Victoria, quoted in Joseph, 2007, p. 116). Not surprising, Joseph found that the fragmentation strategy took a great toll on the students in terms of time and emotional energy.

Ong (2005) also found instances of fragmentation in her longitudinal ethnographic and interview study that included four women of color graduate students in physics. Whereas Joseph (2007) identified fragmentation among her interviewees to exist between academic identities and predominantly racial/ethnic identities, Ong identified fragmentation between academic identities and predominantly gendered identities. For example, one Chicana Ph.D. candidate described how, for years, she wore baggy brown and gray clothing to the laboratory but wore pink items from her wardrobe when she was not around labmates (Ong, 2005). A Latina student described how, for the purposes of seeming confident when speaking with her physics peers, she had to

“un-learn” prefacing her comments with words like “*I think...*” or “*I am not sure, but...*” and instead say, “*This is the way it is*” (Ong, 2005, p. 605-6). Like the students in Joseph’s study, the students in Ong’s work spent a lot of time and energy anticipating reactions from their departmental peers and faculty. They worried about not being taken seriously because of what they wore or how they sounded. It often pained them to have to deliberately hide parts of themselves for the sake of gaining acceptance into their scientific communities.

Mentorship and Role Models

Mentorship, a formal or informal professional relationship whereby a more experienced person traditionally gives support and advice to a less experienced person in the field, is often cited as a vital element in promoting women of color in non-traditional fields (e.g., Burlew & Johnson, 1992; Ong, 2002; Sader, 2007). For women of color doctoral students in STEM, their mentors often played important roles in women’s decisions to attend graduate school, choose a particular doctoral program, and/or to stay or leave their programs. In Hall’s (1981) MWIS survey study of minority female STEM professionals, respondents recommended mentoring programs for women of color as a way to increase their completion in graduate science programs.

Sader (2007) conducted an interview study that included a diverse group of ten female doctoral students in computer science, including one African American and four other minority women who were born outside of the U.S. (due to the parameters of the synthesis, the experiences of the latter four are not discussed here). The author reported that Camille, the African American woman in the study, had returned to school after 22 years working in business, and was going to be the first African American female to graduate from her university with a Ph.D. According to Sader, Camille attributed at least some of her success to an African American female mentor from her previous workplace. This mentor helped Camille move up the ranks while they worked in business together as well as influenced Camille’s interest in computer science.

Once in graduate school, faculty mentorship for women of color is rare but incredibly valuable. Reporting on data from a large survey study of minority women who had entered or graduated from science and engineering graduate-degree programs, S.V. Brown (2000) noted that “few minority women had true mentors while in graduate school, but those who did reported exceptional relationships and experiences” (p. 259). Evidence from MacLachlan’s (2006) and Joseph’s (2007) work supports this statement. MacLachlan (2006) found that, perhaps not surprisingly, women who completed Ph.D.s rated the mentorship of their graduate advisors as highly influential. One Chicana in her study said that her mentor “gave me training that allowed me to succeed and be professional.” An African American woman explained that from the mentoring relationship “I gained a lot of independence, self-reliance. This has been helpful in terms of initiating new activities and programs in my environment and to develop confidence in my ability” (p. 240).

Another illustration of the effectiveness of mentoring comes from Joseph’s (2007) qualitative study. Joseph reported that one African American woman, Kerry, was deciding to not attend Duke’s mathematics Ph.D. program, but changed her mind when a Black, Belizean-born

professor called and promised that he would mentor her. In her first year, the mentor gave Kerry helpful advice, for example, that “she become visible in the department” as the department’s speaker events coordinator, and that she maintain a “strong distinction between her role as a graduate student and her personal interests” (p. 90). In following her mentor’s advice, Kerry felt that she was able to better cope with the social isolation she felt in her department and therefore persist in her graduate studies.

We only found one scholar, S.V. Brown (1994, 2000), whose empirical work addresses the effect of the presence or absence of role models on women of color’s experiences in STEM at the graduate level. Drawing from a large survey of female and male and minority and nonminority graduate students, S.V. Brown (1994, 2000) reported one major finding that, relative to the beliefs expressed by their minority male and White female counterparts, women of color believed that the lack of faculty role models was a disadvantage to them. Moreover, minority women in engineering and the physical sciences were more likely than those in life sciences to indicate feelings of disadvantage.

Faculty Influences and Support

As mentioned in the previous section, when women of color receive mentorship from faculty members, the relationship can serve as a valuable resource for women’s retention in STEM. Unfortunately, strong mentoring relationships are very rare (S.V. Brown, 1994, 2000; Hall, 1981; MacLachlan, 2006). Instead, our synthesis reveals women of color who, by and large, are negatively affected by faculty members’ social discrimination. A professor’s cultural bias against women and/or minorities, whether conscious or not, can potentially play a significant role in undermining the success of women of color in STEM. S.V. Brown (1995) tested the “double bind hypothesis” to see whether minority women were “doubly disadvantaged simply because they are both minorities and women” by conducting a quantitative, secondary analysis of data—including faculty and scientists’ scores of applicants, race/ethnicity, sex, and undergraduate grade point average (UGPA)—from the Cumulative Index on the NSF Fellowships Applicants and Awardees between 1976 and 1991 (Brown, 1995, p. 207).

S.V. Brown’s (1995) study considered 62,966 unique applicants, of whom 12,660 were minorities and 6,670 were minority women (p. 211). By applying Ordinary Least Squares multiple regression, using faculty and scientists’ anonymous ratings of applicants (1 to 6) as independent variables and race/ethnicity and sex as dependent variables, Brown found that “minority women had the lowest probability of being rated truly exceptional or outstanding by referring scientists and faculty. Their scores were lower than those of minority men, white women, and white men” (S.V. Brown, 1995, p. 259). Brown asserted that the findings supported the double bind hypothesis because they showed that “above and beyond being a woman or a minority, being a minority woman, has a greater negative impact on faculty/scientists’ recommendations,” and that this finding held true *even when UGPA and degree field majors were controlled* (S.V. Brown, 1995, pp. 219, 207). Furthermore, the author found that the minority women’s *identifiability* was a factor in faculty and scientists’ ratings of applicants.

When only considering high-ability men and women (as defined by their UGPAs), the author found that those students who might “pass” as White and U.S.-born American received different treatment from those who could not disguise their skin or accents⁶:

[B]eing talented appears to leverage the recommendations of American Indian and Mexican-American women, making their recommendations comparable to high-ability white women. However, compared to high-ability white women, being a talented Black, Puerto Rican, or Other Hispanic woman had a significant negative impact on the recommendations submitted by faculty and scientists. (S.V. Brown, 1995, p. 219)

Brown concluded that recognizable differences of sex, race/ethnicity, and language put certain groups of women of color at an unfair, undeserved disadvantage when it came to faculty’s assessments of their abilities.

Faculty members’ negative assessments of women of color may stem from other reasons, as well. Solórzano (1995a, 1995b) conjectured that because the majority of Chicana and African American women (and men) who pursued science and engineering doctorates attended MSIs and/or “less prestigious” undergraduate institutions, they entered their Ph.D. programs with the distinct disadvantage of lower expectations from professors. MacLachlan (2006) reported that the women of color in her study received from faculty subtle cues about their perceived token and inferior status:

[The interviewees] commented on subtle changes in [faculty] behavior suggesting they did not belong, that they were seen as ‘a’ or still ‘the’ minority, not as a student or a potential colleague. The women of color felt that they were not seen as themselves, as persons, or future scientists, but as ‘representatives of their race,’ and were scrutinized and judged on that basis. (p. 242)

In their six-year interview study of 15 successful women of color in science, Carlone and Johnson (2007) learned that at least one Hispanic female student in their study experienced such low judgments. While an undergraduate struggling in her science major, one of her professors recommended that she leave science. Instead, she persisted. Years later, as a graduate student, she saw him at a conference and took satisfaction in telling him that she was first author of a project. The professor expressed surprise but, sadly, still failed to recognize her as a legitimate scientist (Carlone & Johnson, 2007, p. 1206).

Outreach

A common finding across empirical research on women of color in graduate STEM programs is that the students—particularly African American women—were active, or planned on being active, in reaching out to other women, minorities, and women of color to draw and retain them in STEM fields. For example, Sader’s (2007) ethnography included an African American female doctoral student in computer science who said that she hoped to enter into the academic sector to help recruit more women and minorities to her field. Sosnowski (2002)

⁶ Brown (1995) did not distinguish between U.S.-born Hispanic and non-U.S.-born Hispanic populations.

reported a similar finding about an African American engineering Ph.D. student, Grace, in her phenomenological study:

Grace believes in the importance in being a role model, a gatekeeper for those coming up the ranks in engineering. She knows just how important it is to encourage younger women of color to fields in SMET. She is excited about teaching and embraces the challenge and joy that comes in helping others to realize their dreams as her own dreams become a reality. (p. 115)

Joseph’s (2007) ethnography and interview study of six African American women at the beginning of their graduate careers in PWIs revealed that the majority of the students planned educational and career trajectories that included mentoring and serving as role models for younger minorities and women.

Finally, Ong’s (2005) longitudinal, qualitative study reported how one African American Ph.D. candidate in business and science was overcommitted because of her studies and her time spent in trying to start a new business; even so, this student kept active as a leader in the student government, with her main activities related to recruiting underrepresented students to her predominantly White graduate school. The student explained, “When you’re Black in a Black community or female at an all-female college, it doesn’t really matter. But when being a Black woman is the very thing that separates you, your race and gender become paramount” (Kendra, quoted in Ong, 2005, p. 608). Ong’s (2002) research also featured a Latina woman who attributed some of her persistence in her physics Ph.D. program to her participation in an informal group of graduate women in science, which she helped to lead. Speaking about this leadership role, she said,

I’m as much a physicist as anybody else, so how do you define a physicist? By who’s in physics. Well, I’m in physics. So you have to define it with me in it, too. The fact that there’s very little of me or of women is not something that I like. In my little ways I’m trying to change that. (Laura, quoted in Ong, 2007, p. 7)

Another Latina graduate student in physics, Elena, who participated in Ong’s (2005) study, took a different tactic in transforming the populations that are recruited to science. Elena spent a year organizing and implementing fun science lessons to predominantly minority elementary school children in an urban school district.

Graduate Training, Networking, and Future Career Opportunities

We identified two empirical works that addressed graduate-level training, networking, and career building. Hall’s (1981) survey study of professional minority women in STEM included a section soliciting suggestions to retain women of color in graduate school. Respondents stressed the need for the inclusion of women of color in co-op programs, high quality research training, and the development of formal and informal professional networks. Joseph’s (2007) study supports the importance of these networks. A mathematics Ph.D. student in the study explained the importance of her participation on the campus-wide Association for the Concerns of African-American Graduate Students:

This is a group that offers an opportunity for African American graduate students to network with each other, participate in campus activities, socialize, and discuss issues that affect us on campus and in society. This is a great way to connect with others who understand what you go through on a daily basis in some form or fashion. (Shavanna, cited in Joseph, 2007, p. 99-100)

Looking to the future beyond graduate school, respondents to Hall's (1981) study also emphasized the importance of having strong and widely available career counseling and job placement and highly publicized job announcements and grant opportunities (p. 14).

Our searches did not reveal a single empirical study about women of color postdoctoral fellows.

SECTION FIVE: WOMEN OF COLOR IN STEM CAREERS AND WORKFORCE

This Section synthesizes the empirical research on women of color in STEM fields and documents the successes and barriers they encounter in their careers and in the workforce. Women of color in STEM careers can be found in three broad areas: academia, industry and government.

Over the past 25 years, employment trends documented by the Commission on Professionals in Science and Technology (CPST) and the National Science Foundation (NSF) on the representation of U.S. women of color in STEM non-academic occupations have indicated moderate increases (CPST, 2007; NSF, 2007). The participation of African American women in STEM industry and government careers increased from 5.5% in 1994 to 6.2% in 2004. For Hispanic women, participation increased from 3.7% in 1994 to 5.3% in 2004 (STEM Workforce Data Project 1994-2004). Current statistics from the U.S. Department of Labor (2007) indicate Hispanic women are the fastest growing group of employed women in the U.S., followed by Hispanic males and Black women.

Even though white males still constitute the majority in the STEM workforce, women and racial minorities have made inroads in the past four decades in public, private and academic institutions from the late 70's through 2006. (White, 1992⁷; Gries, 1986, 1990, 1989, 1992). The representation of U.S. women of color in STEM academic careers has improved over the last quarter century. In the 2005-2006 academic year, women of color held 2.8% of the positions with the rank of Professor, 5.8% with the rank of Associate Professor and 8.5% with the rank of Assistant Professor (*The Chronicle of Higher Education, 2005-6 Almanac*). However, while there have been small increases in certain disciplines over the last 25 years, the relative numbers of faculty of color in STEM and their subsequent advancement through the ranks is still very disappointing. At any given career stage, women of color are more likely to hold lower ranks than White women. That is, women of color are concentrated in lower-status positions in academia in STEM, including lower status institutions and early tenure-track ranks (Nelson, 2004; NSF, 2007). The United States continues to struggle to build diverse faculties in STEM disciplines across its campuses.

The following section is presented in three parts. The first part synthesizes work on women of color's historical and contemporary status in the workplace in STEM. The second part focuses on the career choice and early experiences of women of color in STEM. The third part synthesizes issues regarding women of color's experiences and conditions in the workplace and their career development.

The Historical and Contemporary Landscape for Women of Color in STEM

In 1981, Maxfield looked at employment of minority Ph.D.s over a twenty-year period.

⁷ Work by White (1992) provides a comprehensive descriptive analysis of the relative statuses of different gender/racial groups in STEM management occupations as well as careers in academe.

The study used data from the *NSF Survey of Earned Doctorates* from 1960 to 1979. The sample consisted of 32,877 recipients and stratified in to six categories: field, year, degree category, gender, race/ethnicity, and citizenship. According to the data, of STEM Ph.D.s awarded during this time, minority women were significantly underrepresented compared to the minority men in their respective racial/ethnic groups. Black women had the highest female-to-male ratio among racial/ethnic groups; compared to Black men, Black women were awarded 22% of Ph.D.s from 1960-1969 and 30% from 1970-1979. Relative to the men in their racial/ethnic groups, Hispanic women earned 8.6% and then 12.3%, Asian American women were awarded 5.4% and then 22.5%, and Native American women received 5.6% and then 18.3% of STEM Ph.D.s from 1960-1969 and 1970-1979, respectively.

Now, two decades later, statistics show that the employment status of minority female Ph.D.s has indeed improved (NSF, 2007). Unfortunately, however, we found little empirical research on the career success of women of color in STEM fields exclusively. In the work that we found, research on women of color was embedded within studies of African American faculty and/or women scientists in academic settings (e.g., Fox, 2005; Lucero, 2002; Maxfield, 1981; Williams, 2000). We identified one empirical paper about employment and pay of female and minority scientists and engineers in the federal and private sector. In this paper, Lewis and Soo Oh (2008) found that women and minorities with STEM degrees in these fields earn as much as comparable men and Whites. They concluded that STEM occupations were moving from being a source of pay disparities to becoming a new path to equality for women and minorities. While Lewis and Soo Oh's (2008) message is hopeful for approaching equity in the STEM workplace for women of color, the authors also point out that equal pay was only *one* factor in achieving full equality. Other major obstacles must be identified and addressed if workplaces in the federal and private sectors are to retain women of color and other underrepresented groups.

Unfortunately, the contemporary landscape in academia is not as positive as it is in industry and government. While there is a growing number of women of color who are completing undergraduate and doctoral degrees in STEM fields, they are not matriculating into STEM faculties and departments. A survey conducted between the years of 2002 and 2007 found that minorities and women faculty are underrepresented in the fields of science and technology among the top 100 departments of science and engineering in the United States (Nelson, 2007). During these years the numbers of underrepresented faculty of color increased by .5% to 5%, but women of color in STEM remained extremely low (Nelson, 2007). Given the increasing numbers of underrepresented women of color with doctorates in STEM fields, their share of faculty positions should be much greater. This discrepancy can be partly attributed to the fact that once in academia, African American and Latina/Chicana women are the least likely groups to be full professors or to receive tenure at 4-year institutions. Only 29% of all African American and Latina/Chicana females were tenured in 1997, whereas 38% of White females and 63% of White males held tenure (Leggon, 2001). Furthermore, Native Americans comprise only 0.4% of engineering faculty (NSF, 2007).

Career Choice and Early Experiences of Women of Color in STEM

Career Choice of Women of Color in STEM

With the exception of personal reflections and narratives, little is known about the quality of the collective experiences of women of color in STEM fields. Research has not tapped fully into the STEM experiences of women of color, but some studies have begun to delve more deeply into their professional choices and career trajectories. Two articles were found that focused specifically on career choices of women of color in STEM fields; both examined the STEM career interests of African American women. Obleton (1984) conducted a qualitative interview study on career choice among African American professional women. The sample consisted of twelve African American women scientists and engineers, as well as fifteen African American women doctors and nurses in the state of Arizona. This study documented that African American professional women in science, engineering and medicine saw their status as African American and female as influencing their career trajectories. Family was the main reference group for these women, closely followed by school personnel. Women reported being socialized to accept the role of worker and mother and were made aware of the possibility of being stereotyped on two dimensions, family focused and members of a racial minority group. The women further indicated being influenced by early life exposure to science, yet in later years, they lacked information on how to advance their science careers. Overall, Obleton (1984) concluded that despite the awareness of a narrow opportunity structure among STEM occupations, within their chosen field, the African American women in the study had aspirations to further their achievement and 77% had supervisory positions within their job category.

Figgers (1998) studied the influences that encouraged three African American women, raised during three different sociopolitical eras, to pursue mathematics as a study and as a career. Three major categories of influence emerged as contributing to their pursuit of mathematics as a major and career: significant others, family associations, and Fine Arts. When examining the conditions that encouraged these individuals to pursue a career in mathematics, educational opportunity, teacher, and job opportunity were cited as major influences. These studies were consistent with the literature claiming that contextual supports, role models and access to information were important to womens' decisions to choose a career in STEM and think they will ultimately be successful in that occupation. More research is needed on where family influences interact with STEM occupational choice and subsequent attainment to leadership positions.

Other than the scholarship discussed above on African Americans, no additional research on the career choice of women of color in STEM fields was found.

Early Career Faculty Experiences of Women of Color

Our search discovered one research article that explored the concerns of early career women faculty of color in STEM fields. In an in-depth, phenomenological study of the early career experiences of African American women by Lucero (2003), ten engineers, mathematicians, and biochemists were asked to discuss how they negotiated their academic environments as well as the sources of messages that affected this construction and negotiation.

The women reported their early faculty career experiences as mostly dynamic, where identification with work was multifaceted and complicated. Like their nonminority counterparts, they reported understanding and achieving expectations for tenure, becoming socialized into the formal and informal aspects of their departments, and balancing demands of work and family as important concerns in their early careers. In addition, the early faculty career experiences of African American women in the study were characterized by a process in which they rejected negative representations of African American women in the academy, reaffirmed their own identities, and redefined their own realities by re-interpreting and proactively responding to mixed cues in their academic environment.

The African American women faculty in this study also reported exerting a lot of emotional and physical energy trying to resolve tensions between their needs and those of the institution. Frustrated by a lack of clear, complete, and consistent information about tenure and promotion, their sense of trust in peers and colleagues began to erode. Lucero (2003) concluded that the women in this study were “successful women with wounded spirits” because despite the progress of faculty women of color, the proportion of those who received tenure was low. In addition, the few women of color who were hired for tenure-track positions in academia were often asked to assume multiple committee assignments, campus diversity work, and administrative duties before receiving tenure. At some institutions of higher education, committee work can count towards tenure, however, this work often removes the junior faculty member from their research, undermining their advancement due to time away from research and teaching.

We found no empirical research addressing the experiences, barriers and facilitators to advancement, of women of color in STEM during the mid-career or advanced-career stages.

Women of Color’s Experiences and Conditions in the Workplace and Their Career Development

Experiences and Conditions in the STEM Workplace

There exists an image that Asian Americans are a homogenous, hardworking group who are overrepresented in the sciences and engineering. Empirical data on Asian Americans in the STEM workplace challenges widely held stereotypes about Asian Americans, including the perception that they cluster in STEM fields.

Yan (1999) analyzed data from the *1982 Survey of Scientists and Engineers* conducted by the Bureau of the Census for NSF, which tracked both race and ethnicity while exploring the education and work experiences and conditions of female scientists. The original survey targeted 8,451 women, broken down by race into 35 American Indian women, 690 Asian American women, 479 Black women, and 7,100 White women. The author’s analysis focused on understanding Asian American women’s experiences in science compared to other women.

Asian American women represented 5% of all scientists and engineers even though they made up 2% of the total labor force, meaning they were highly represented in STEM as a group.

Asian Americans have often been subjected to the model minority thesis, which attributes their high levels of educational attainment as the main cause for their success. However, Asian American women have very different experiences from their male counterparts and other women from various racial/ethnic backgrounds.

Yan (199) found that Asian American women were more likely to be older; they were more likely than White or Black women to be concentrated in the 31-40 and 41-50 age groups. The author theorized that this could be due to their high levels of educational attainment, which delayed workforce entry. About 75% of Asian American women, she found, worked in the industrial sector and only 13% worked in educational institutions, while the reverse trend was seen for White women. Black women were more likely than other groups to be employed by government. Yan also found that Native American and Black women had higher rates of full-time employment than White and Asian American women, signaling different economic conditions among different groups of women. Asian American women were more likely to be concentrated in technical positions involving basic research, applied research, and development than Black and White women, and were less likely to be in management positions for research, administration or teaching. Also, Asian American women were less likely than other women to be involved in professional societies. Finally, Asian American women held a larger number of higher-paying technical jobs in industrial fields but had lower representation in managerial positions.

Other research documented a more nuanced story about Asian American women in STEM careers. Eng and Layne (2002) analyzed data from a 1991 Society of Women Engineers survey of 22 engineering societies to explore the specific experiences of women engineers. The authors tailored their analysis to focus on a sub-sample 100 men and women who identified as Asian American/Pacific Islander. The analysis explored how Asian American women engineers differed in their lifestyles, careers, and their perception of their success in the engineering field.

Eng and Layne (2002) first pointed out that Asian American women were not underrepresented in engineering. That is, there was no significant difference between the numbers of Asian American women engineers in the Asian American population (8.2%) compared to the number of women in the engineering profession overall (7.7%). However, the authors identified many differences in lifestyle choices. Asian American women tended to be younger than other women in engineering. Over half of the Asian American women engineers were under 30, while only 34.6% of all women engineers were under 30. Asian American women engineers were also less likely to be married or have children than other women engineers, and were more likely to utilize cheaper, private home child care options.

In terms of the work environment, stereotypes that may unintentionally perpetuate the subordinate status of women of color were among the concerns raised. Asian American women were less satisfied than female engineers overall. They were less satisfied than other women with support facilities and advancement opportunities available to them and significantly less satisfied with their supervisors, whom they felt were often insensitive and overlooked them when assigning prestigious projects and assignments. Eng & Layne (2002) also made reference to the cultural expectations for Asian women to maintain a quiet, subservient demeanor and to be heavily involved in family life, two factors which might have affected their advancement in the

engineering field. Similar to Yan (1999), Eng & Layne suggested that differing cultural expectations in the technical aspects of engineering versus expectations in the business and management aspect creates a glass ceiling for many Asian American women scientists. This research suggested a dual-ladder career structure, technical versus managerial, was at play. That is, Asian American women were pushed toward tasks that were stereotypically feminine, such as support work. Women on the technical ladder were more likely to be encouraged to follow a path where “soft skills” were required. Perhaps this represents a significant barrier to Asian American women as they are not afforded a diverse repertoire of behaviors in the STEM workplace.

Tang (1997a) explored NSF panel data to determine whether Asian Americans in science and engineering followed the stereotypical image of the successful model minority - as compared to Blacks and Whites – as they advanced in their management careers in STEM fields. The study is based on a survey of natural and social scientists and engineers (SSE) in the mid-1980s. The sample consisted of 38,059 full-time salaried scientists and engineers with a four-year college degree. Detailed information on career profiles of the participants were collected in 1982, with three follow-ups in 1984, 1986, and 1989. Blacks constituted 4.3% of the sample, 7.5% were Asian Americans and 1.3% were “other.” Logistic regression analysis revealed the following: regardless of gender, Whites account for the bulk of job changes (movement to a managerial position) from 1982 to 1989. During that same period, the growing presence of Asian Americans in engineering occupations coincided with slow progress into management. Further, Asian American scientists have 42% lower probability of entering management than white males. Tang concludes that both market and cultural factors (as well as limitations on the data set) contribute to the differences in career mobility for Blacks, Whites and Asian Americans. Tang cautions others take care to avoid approaching Asian Americans as a homogenous group and uniformly apply the model minority thesis, as is so often the case.

Using the same data set previously mentioned, Tang conducted another study about promotions and career prospects for minority females in science and engineering occupations (1997b). The author looked at the relative statuses of White, Black and Asian American women. Findings indicated that race and gender have a negative effect on the chances of holding a managerial position in stem. Specifically, Blacks and Asian Americans were less likely to be in managerial positions compared to whites, however, Tang found that the “double penalty” applied to Asian American females only. Tang concluded that Asian Americans in STEM occupations held a narrower range of jobs and were more segregated from other groups in relation to Whites. Tang (1997c) also used the 1986 Survey of Natural and Social Scientists and Engineers (SSE) to analyze the career histories of a cohort of Asian American and White engineers to further interrogate the model minority thesis. Tang’s results were similar to those of her previous studies: she found that Asian Americans have done well in terms of access and entry into science and engineering professions, but less well in terms of advancement. Fewer Asian American engineers than Whites were found in management positions. Interestingly, Tang found that although Blacks are underrepresented in STEM occupations, they have better upward mobility than Asian Americans in STEM fields.

Koelewijn-Strattner (1991) explored the professional status (in terms of income and authority) of Black women compared to White women in chemistry. Specifically, the “double negative” and “double jeopardy” (i.e., being both Black and female) interpretations were

examined. Data for this study came from the American Chemical Society’s (ACS) 1985 salary and employment survey; all respondents were professional chemists. Of the final sample (42,638), 109 (.3%) respondents were Black women. Descriptive statistics and Ordinary Least Squares (OLS) regression models were used to predict dependent variables by race and gender. Findings suggested that African American women chemists were neither better nor worse off than their White counterparts in terms of income and work authority, controlling for education, work experience and marital status. Koelewijn-Strattner concluded that within the ACS, Black women were disadvantaged by virtue of being women, but the impact of being both Black and female was unclear. She explained, “[w]hile for some Black women being Black and female may be a liability, for others this combined status might be an asset” (Koelewijn-Strattner, 1991, p.16). Furthermore, the author stated that explaining the effects of race and gender on the professional status of women was complicated by historical differences, socialization patterns and socio-economic structures, factors difficult to capture in a quantitative analysis.

Career Development

The research studies discussed in this subsection make clear the extent to which STEM culture, a lack of mentoring, and perceived racial discrimination still shape the current workplace for African American women. Hanson (2004) used NELS:88 data to track the experiences of young African American women throughout their science education and beyond. After weighting the sample, the author conducted her study of 581 African American and 3,365 White women. For the African American women in this sample, minority-serving institutions (MSIs) produced the most opportunities for advancement in the sciences. Barriers to African American women included sexism, lack of mentors, and lack of awareness of African American contributions to science. While White women throughout high school were more likely to receive higher grades on standardized exams, eight years after high school, African American females were more likely to hold a job in the field of science.

Shenhav (1992) conducted a longitudinal study of the effects of gender and race on entrance into managerial positions in science and engineering based occupations. Data was drawn from a national survey (from 1982-1986) by the U.S. Census Bureau for the National Science Foundation. The final sample represented data on 13,509 respondents - from both public and private sectors - who completed the survey in both 1982 and 1986. This study examined discrimination affecting career progress of those belonging to the labor force and pursuing engineering, scientific, or related occupations. The results reveal higher proportions of women and African Americans in the public sector than in the private sector and identical proportions of African American and White workers were found in the private sector. In terms of promotion rates overall, African Americans had higher rates of promotion than Whites (23% and 21% respectively). In the private sector, the corresponding numbers are 17% for African Americans and 21% for Whites. Overall, African Americans workers enjoyed better promotion opportunities than Whites in both sectors. Opportunities for women were significantly better in the private sector. Ultimately, Shenhav concluded that no firm conclusions about the existence of discrimination could be made without a logit analysis. To account for selection bias, methodological considerations need to be taken into account for a more detailed and accurate understanding of the data. Shenhav cautioned that cross-sectional studies can be misleading as they can easily miss trends in the data.

Tharp’s (2002) research explored the factors that influenced the career development of female engineers. Using both questionnaires and in-depth interviews, Tharp analyzed the self-efficacy, supports, barriers, and strategies to cope within a male-dominated profession, and female engineers’ recommendations for improvement. The author recruited 26 female participants who worked in engineering, made up of 11 European Americans, eight Native Americans, five Hispanics, and two African Americans. When asked about race discrimination at work, several minority women who were highly conscious of race and gender discrimination were more likely to be “challengers,” meaning they would not attempt to fit into the male-dominated culture but were more likely cope by attempting to change it. Two Native Americans, two Hispanics, and one African American felt they had embodied the challenger role during their engineering career.

Tharp also observed that the closer a women of color was to “White,” meaning lighter in skin tone, the less likely she would experience overt racial discrimination. Tharp’s two African American participants both shared stories of very unwelcoming work and academic environments, and both suspected racial discrimination played a role in their lack of advancement and lack of job offers. One woman said she was both the only female and only minority at her company, and she felt alienated by her co-workers who choose not to socialize with her. Tharp’s overall conclusions were that personal, educational, and professional supports, particularly through opportunities for career-related experience, increased self-efficacy among her participants. The author also noted that overcoming racial and sexual barriers increased self-efficacy, especially if receiving environmental support (Tharp, 2002). She emphasized that women in color, in particular, faced structural barriers both in academia and in the professional world and lacked roadmaps for how to successfully progress in their careers.

Kvasny (2006) conducted the only study found that exclusively studied information technology (IT) and women of color. This small, interview study focused on the experience of 10 working-class African American women in an IT training class. The interviews were short, unstructured and informal in nature and were conducted over an eight-month period. Kvasny found that the most prevalent theme in the interviews was one of upward mobility. All the women in the study believed IT training represented opportunity for change and upward mobility in their lives. However, Kvasny also pointed out that although the women in the study did receive basic computer literacy skills and increased confidence from the class, the IT training in no way engaged the larger context of participation in the IT workforce or how the women might move into higher paying jobs. Many of the women were frustrated they did not receive the anticipated benefits. Kvasny suggests that current theorizing about race and gender in IT is limited. That is, current research in IT is too narrowly focused on high skilled, high paying IT occupations and too often leaves out working-class perspectives on participation in the IT workforce.

Integration of Work and Family

There are multiple forces that influence why women leave STEM fields, however, integrating career and family stands out as a major challenge to career advancement. Many studies document the struggles and tensions involved with career and family. For example,

women who want to be mothers cannot often delay childbearing until after their career has been established. Hence, they are often forced to choose between success in science or being a mother. Women often don't want to have concerns that high levels of family engagement will translate into being taken less seriously at work. Whether single or partnered, women do not want to sacrifice prestige, influence, and tenure for family life. We suspect similar issues of family and work balance affect women of color in STEM, but we cannot be sure as we found no empirical work that specifically looked at these issues with women of color. The research that exists in this area looks at women broadly, but the data are not disaggregated by race. The extent to which the same tensions play out for women of color in STEM can only follow from empirical work that looks specifically at what issues exist for women of color in STEM, why they matter and how these women navigate them. The intersection of career experiences, identity, race and family is a fruitful area of research. The challenge is to explore what would it take to keep brilliant women scientists in the field, even as they bear and raise children.

The experiences of women of color, their pathways to work, including hiring and retention practices, play a critical role in how the STEM workforce will evolve. All women of color are underrepresented in STEM professions relative to their increasing share in the labor force. Evidence of bias calls for better, more comprehensive data collection, information, and story sharing about who gets entry into and stays in the STEM workforce in academe, industry and government.

SECTION SIX: CONCLUSION AND RECOMMENDATIONS

The *Inside the Double Bind* study identified several characteristics across the undergraduate and graduate experience, namely: the difficulties of transitions between academic stages (i.e. high school to college, community college to four-year institution, college to graduate school) and transitions from minority serving institutions to predominantly White institutions; the critical role that social climate – including issues of isolation, identity, invisibility, negotiating/navigation, micro-aggressions, sense of belonging, and tokenism – plays in women’s satisfaction and retention in STEM; and the positive, as well as negative, effects of words and actions by faculty who serve as mentors, role models, teachers, and authorities on the intelligence and abilities of their students.

At the career level, employers and institutions need to pay more attention to attracting, recruiting, mentoring, and promoting women of color. The race and culture dynamics of professional workspaces are very important to career productivity and mobility. There is ample evidence (both anecdotal and research based) that racial stereotypes and cultural/racial discrimination (both subtle and explicit) persist throughout the hiring and promotion process for women of color in STEM careers. The particularistic norms of the scientific community can lead to the exclusion of women of color from the workplace milieu, often very important to career success. Institutions should be more aware of organizational dynamics and the qualitative “feel” of formal and informal professional networks and how they are linked to the career trajectories of women of color in STEM.

While great strides have been made in empirical research over the past 30 years, and especially over the past decade, in understanding strategies for success and challenges in promoting women of color in STEM, there clearly are many more areas that must be addressed before we may find ways to fully realize the potential of this great, untapped resource. As it is the hope to provide a base of knowledge from which researchers, educators, scientists, civil rights groups, activists, and policymakers can move forward in their work of advancing women of color in STEM, the final section of this manuscript broadly outlines a research agenda for the next decade toward this goal.

Research Agenda

Empirical research on women of color in STEM at the undergraduate, graduate, and early- to mid-career levels has certainly come a long way since the seminal AAAS *Double Bind* (Malcom, Hall, & Brown, 1976) paper. As previously stated, over half of the studies collected under the guise of this project were conducted and/or published since the year 2000. This is promising in that researchers are clearly taking notice of the need to address both gender and race/ethnicity in STEM education and careers. Yet, there is a long way to go before we can truly understand those environments and experiences that both promote and hinder the advancement of women of color in scientific and technical fields.

Perhaps most notable is the need for large, national longitudinal datasets from which quantitative researchers can draw meaningful samples of women of color in all STEM fields.

Regarding specific sub-populations, research on African American women in science represents a substantial portion of the literature. We need to bring other racial/ethnic groups into this fold through increased study of Chicana/Latina, Native American, and Asian American women in STEM. Beyond racial/ethnic diversity is the need for studies inclusive of geographical and socioeconomic diversity, as well as work that addresses transitions and points of loss between the secondary, postsecondary (2-year, 4-year, and graduate institutions), and career stages of the STEM pipeline. In support of this work is a final overarching need for theoretical and conceptual frameworks that address women of color in STEM as a stand-alone population.

Future Research: Undergraduate Women of Color in STEM

The scholarly contributions made to the field of undergraduate STEM education for women of color cover a wide range of collegiate environments and student experiences. While this is cause for celebration, the gaps in this literature base are many. Particularly given the fact that undergraduate education marks the first point of entry into the postsecondary pipeline, and further influences graduate school and career aspirations, it is essential that research continue to explore how colleges and universities can best support women of color pursuing STEM majors.

A significant challenge in understanding the pathways that women of color take through postsecondary education is the lack of national-level data that tracks STEM major retention between college entry and graduation. This is especially true for students that take non-traditional paths, such as beginning undergraduate study at a community college or those who are enrolled in college part-time. Understanding the impact of unique institutional environments is also important. Although the literature has shown HBCUs as providing a distinct environment for women of color in STEM, there is no known study that addresses the academic and social environments of HSIs or TCUs.

Perhaps most salient to individual colleges and universities are findings that support the need to address STEM pedagogy and curriculum for diverse populations. By understanding how STEM professors can better engage students in scientific learning comes a potential stream of research on the relationship between pedagogical changes and cognitive outcomes for women of color; two areas that are lacking in the current literature base. In addition to innovative and supportive academic environments, there is need to further study campus-based resources - such as academic advising - that support pre-graduate school preparation. An updated survey of women of color professionals, like that of Hall (1981), addressing the long-term impact of undergraduate experiences in STEM would complement a growing body of literature that follows women throughout the STEM pipeline.

Finally, the role of influential individuals - such as professors and peers - needs further exploration. Specifically, the role of mentoring in formal and informal settings both in and outside of organized STEM retention programs. While there has been much research on the impact of these programs for STEM students on the whole, there remains a lack of understanding of how programs can support women of color in particular.

Future Research: Graduate Women of Color in STEM

Existing research, written between 1970 and 2008, on women of color in STEM at the graduate level covers a wide range, including: the parity status of different groups of women of color; the baccalaureate origins of Chicana doctoral recipients in STEM between 1980 and 1990 and of African American female doctoral recipients in STEM between 1975 and 1992; and minority women’s academic preparation and transitions from college, family influence and support, funding, social climate, mentoring and role models, faculty influence and support, outreach, and graduate training. While this is a good foundation, there are, unfortunately, many gaps in the literature as well as many studies that need to be updated. Also, research is certainly needed on all disciplines at the Ph.D. level, but researchers may want to remain aware that women of color are especially underrepresented relative to White women and all men in physics, computer science, mathematics, and engineering. Learning more about women of color in these fields may help address their underrepresentation.

Transitions from the undergraduate level to graduate school in STEM for women of color need to be further addressed, both through quantitative and qualitative research. Specifically, researchers need to conduct updated, large-scale studies on parity status and baccalaureate origins of women of color in STEM by each racial/ethnic group – similar to those of Solórzano (1995a) and Leggon & Pearson (1997) – to include the 1990s and early 21st century data. Research is also needed on students making transitions between undergraduate STEM training in minority-serving institutions to graduate training in predominantly White institutions.

Future scholars are encouraged to conduct more studies on institutional characteristics and environments that aid or hinder women of color graduate students in STEM. Possible topics include the influences of funding, the effects on women of color of recruitment and retention programs and other diversity programs, non-traditional pathways through graduate programs, the effects of the presences and/or absences of role models and mentors/coaches (including traditional, peer, and community mentors/coaches), and the impacts of social climate issues and implicit bias in the experiences and advancement of women of color graduate students. The survey study of minority women STEM professionals (Hall, 1981) provided key insights improving the experiences of current women of color in graduate school, but the findings are nearly three decades old; a new survey study should be conducted. Also, looking just beyond graduate school, almost nothing is known about women of color postdoctoral experiences.

Lastly, there needs to be more systematic and rigorous research on the influences of family for women of color graduate students. Research should address the roles that parents, siblings, and extended family, as well as students’ spouses/partners and/or children, play on the experiences and advancement of women of color in STEM. Studies should extend to non-traditional families, including single-parent households and non-heterosexual partnerships. Finally, as many women are in graduate school during the years that are culturally considered peak child bearing years, studies should formally address family and education/career balance issues that are specific to women of color in STEM.

Future Research: Women of Color in STEM Careers

Our synthesis project uncovered some important empirical work on the career choice and early experiences of women of color in STEM, especially those of Asian Americans and African Americans, and on women of color’s experiences and conditions in the workplace and their career development. Much of the work was trend data or survey data analysis. We found many gaps in the literature, which are described below.

The field needs more research on recruitment practices at all career levels of women of color by industry, academia, and government. Very little is currently known about processes of STEM career development and experiences of women of color by specific race/ethnicity. The field would further benefit from comparative research on career development and advancement, especially beyond African American-White and male-female differences. There also must be more exploration of career experiences and advancement by specific STEM field, especially in fields where women of color are least represented: physics, computer sciences, engineering, and astronomy/astrophysics. Presently, almost nothing is known about Chicana/Latina and Native American women in STEM careers.

Little is known about women of color who began careers in the STEM field and then left. A compelling study would be comparative research on career choice and levels of success of women of color who began in STEM and stayed versus those who left. Future research should also address experiences, barriers and facilitators to advancement, of all women of color in STEM during the mid-career or advanced-career and leadership stages. There especially needs to be in-depth examination of why African American and Asian American women have stunted upward career mobility and why they are concentrated at the lower end of the occupational hierarchy in academia, industry, and government positions in science and engineering.

Studies of the STEM workplace environment would also be valuable, especially studies of race, gender, and culture dynamics of professional workspaces and how they relate to women of color’s career productivity and mobility. The knowledge base also needs more research on mentoring and coaching (types, amounts, consistency, junior and senior, formal vs. informal, effective methods) at the career level. Finally, while much is known about women in general regarding the work-family balance, very little empirical knowledge exists about this topic with regards to women of color.

Finally, more qualitative research is needed in the area of STEM careers. The body of work on women of color at all levels and in all areas of STEM careers lacks in-depth, qualitative studies compared to the collection at the undergraduate and graduate levels.

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