Inside the Double Bind: A Synthesis of Empirical Research on Undergraduate and Graduate Women of Color in Science, Technology, Engineering, and Mathematics

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In this article, Maria Ong, Carol Wright, Lorelle Espinosa, and Gary Orfield review nearly forty years of scholarship on the postsecondary educational experiences of women of color in science, technology, engineering, and mathematics (STEM). Their synthesis of 116 works of scholarship provides insight into the factors that influence the retention, persistence, and achievement of women of color in STEM fields. They argue that the current underrepresentation of women of color in STEM fields represents an unconscionable underutilization of our nation's human capital and raises concerns of equity in the U.S. educational and employment systems. They refute the pervasive myth that underrepresented minority women are less interested in pursuing STEM fields and then present a complex portrait of the myriad factors that influence the undergraduate and graduate experiences of women of color in STEM fields. Finally, the authors discuss the policy implications of their findings and highlight gaps in the literature where further research is needed, providing a knowledge base for educators, policy makers, and researchers to continue the mission of advancing the status of women of color in STEM.

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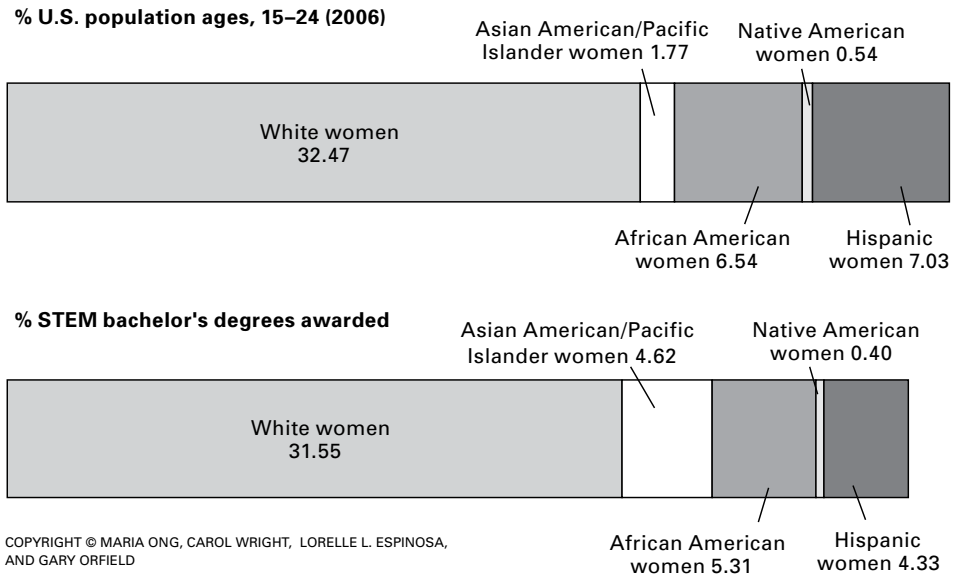
Introduction

Improving recruitment and retention in science, technology, engineering, and mathematics (STEM) fields 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, 2010a). Our nation consistently lags behind many developed countries in terms of quantity and quality of K–12 STEM education. Currently, only about 16 percent of undergraduates in U.S. institutions receive degrees in natural sciences and engineering, compared to 47 percent of undergraduates in China, 38 percent in South Korea, and 27 percent in France (National Academies, 2010a, p. 49). With American and international corporations searching globally for the best and brightest workers in the scientific and technological sectors, an emergent question is whether Americans will be able to compete for such quality jobs. Furthermore, the urgency of regaining U.S. global leadership in science and mathematics has been noted repeatedly by American presidents, including Barack Obama (2009), who recently described science as "more essential for our prosperity, our health, our environment, and our quality of life than it has ever been before."

One critical component of the U.S. response to these challenges must be to invest in the potential of *all* Americans by building a robust workforce in STEM fields (National Academies, 2010a, 2010b). Women and racial/ethnic minorities, and especially women of color—women from African American, Asian American/Pacific Islander, Chicana/Latina, and Native American groups[1]—represent tremendous untapped human capital and could further provide a much-needed force for sustaining America's economic vitality (CEOSE, 2009 and forthcoming; National Academies 2010a, 2010b). Yet data show that while these groups, especially underrepresented minority (URM) women (African Americans, Chicanas/Latinas, and Native Americans), have been awarded more STEM degrees as measured in absolute numbers since the 1970s, they have been consistently underrepresented at advanced education and career stages in most fields relative to White women and men of any color (Burrelli, 2009; NSF, 2009). Moreover, URM women remain *proportionally* underrepresented relative to their representation in the U.S. population and compared with White and Asian American/Pacific Islander women (see figure 1; NSF, 2007; U.S. Census Bureau, 2009).

Failure to advance the education of women of color and move them into productive STEM careers represents a failure of the United States to maximize our own talent pool at a moment when we can ill afford it—socially, technologically, or economically. The United States is in the midst of a historic demo-

FIGURE 1 *2006 female U.S. population (ages 15–24) and STEM bachelor's recipients for selected racial/ethnic groups.*



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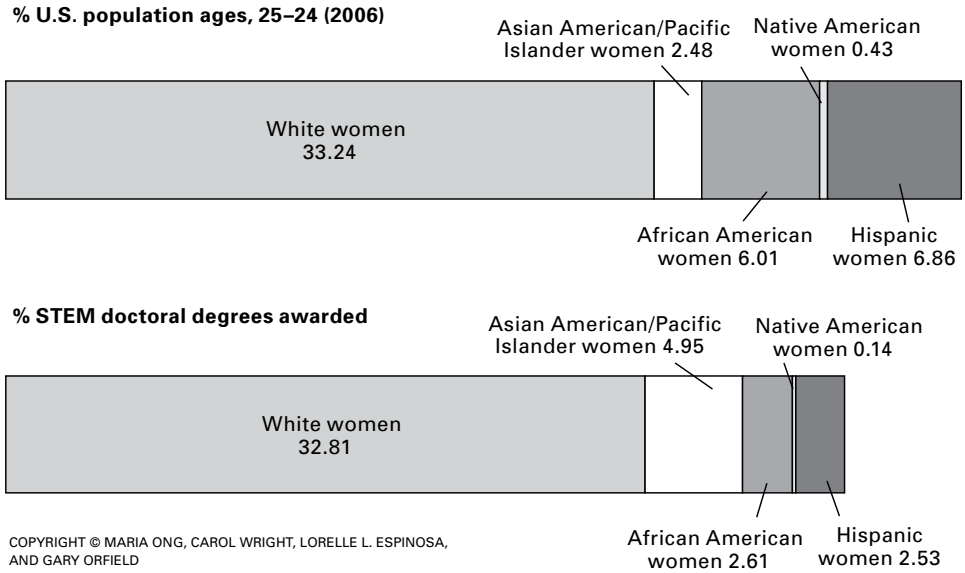
graphic transformation, which means that White men—the traditional source of STEM professionals—are now a continually declining share of the population (U.S. Census Bureau, 2011).[2] Most population growth in this generation has come from non-Whites, particularly Latinos (U.S. Census Bureau, 2011).[3] Public school enrollment numbers show that URM females make up more than one-fifth of children in U.S. schools (National Center for Education Statistics, 2009).[4] In the growing non-White population, women drastically outnumber men in terms of the number attending college (College Board, 2010).[5] Yet, as figure 1 clearly illustrates, the awarding of bachelor's degrees to women of color is *not at parity* with their respective representations in the U.S. population. America's scientific community should reflect its population at large.

Unfortunately, the lack of parity is even more severe at the doctoral level. When comparing the representation of women of color in STEM to that of all men, White women, and women of color (not in STEM fields) in the United States at the PhD level in 2006, women of color were severely underrepresented; they collectively earned only 9.9 percent of all doctorates awarded in science and engineering, while their representation in the general U.S. population was 16.4 percent (see figure 2; NSF, 2007; U.S. Census Bureau, 2009). Asian American/Pacific Islander women often have been seen as the exception; indeed, 2006 data show that they earned STEM PhDs at a disproportionately higher rate (4.95%) relative to their representation in the U.S. population (2.48%). However, members of this group—like other women of color—have

FIGURE 2 *2006 female U.S. population (ages 25–44) and STEM PhD recipients for selected racial/ethnic groups*



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been, and continue to be, stuck in junior-level positions and are not advancing to leadership positions at the same pace as their male and White female counterparts do (Burrelli, 2009; Wu & Jing, 2009).

Clearly, the U.S. education system and research infrastructures systematically undereducate and underutilize women of color (NSF, 2009; Nelson, 2007; Ong, Wright, Espinosa, & Orfield, 2010). The daunting magnitude of their underrepresentation in advanced STEM areas represents serious equity concerns that connect with important historical and contemporary issues of social justice in the U.S. education and employment systems. The status of women of color in STEM first came to light in the American Association for the Advancement of Science (AAAS) publication *The Double Bind: The Problem of Being a Minority Woman in Science* (Malcom, Hall, & Brown, 1976). The "double bind" referred to the unique challenges minority women faced as they *simultaneously* experienced sexism and racism in their STEM careers. The report was based on findings from a seminal 1975 AAAS meeting of thirty minority women. Between the late 1970s and early 1980s, regional professional associations formed to serve women of color in STEM (Malcom et al., 1976). It is not a coincidence that the idea of promoting women of color in STEM gained some purchase in the midst of "second wave" feminism, which sought to correct gender inequities (DeVault, 1996) as well as to amplify the rising voices of women of color in the sociopolitical realm (e.g., Anzaldúa, 1987). Since that time, however, the issue has been largely ignored; there have

been no sustained efforts to serve and support women of color in STEM, possibly due to the misguided idea that burgeoning efforts by the NSF and other institutions aiming to serve women *or* minorities would, consequently, serve minority women. Unfortunately, history has borne out the reality that programs intended to serve women disproportionately benefit White women, and programs intended to serve minorities mainly benefit minority males.

If our nation were to achieve equity in STEM fields, instead of allowing minority women to fall through the cracks when it comes to STEM education, the benefits would be many. Gender and racial/ethnic diversification within STEM is importantly linked to the academic and scientific enterprise itself: minority women's unique backgrounds, cultural traditions, perspectives, and experiences could bring dramatically new approaches to scientific discovery and innovation and could be leveraged to help solve the complex technological problems of our time (ACGPA, 2009; Bement, 2009). Likewise, their work would have the potential to improve the quality of life for all Americans, particularly marginalized segments of the population. Just as the increase in women attorneys motivated radically improved sexual harassment and domestic violence laws, so an increase of minority women in science holds the potential for resolving national concerns such as race/ethnicity-based health disparities (Satcher, 2001) and environmental concerns (Taylor, 2009). Beyond benefits in innovation and economic competitiveness, there is a question of justice, which creates an imperative for positive action to overcome the continuing impacts of a history of excluding women of color from full participation in STEM.

The benefits of equity and justice, in conjunction with our country's shifting demographics and national imperative to further scientific innovation and competitiveness, point to the growing importance of understanding, recruiting, and supporting women of color in STEM education. Thus far, however, a key challenge for researchers, educators, and policy makers drawn to this effort has been the lack of a coherent knowledge base about this population. While there has been much research conducted since 1970 on women in STEM and minorities in STEM, the unique, collective experiences of women of color in STEM have been largely excluded from the research agenda. Reasons for exclusion include the field's operating assumption that efforts targeting racial/ethnic minorities *or* women are sufficient to address the needs and status of minority women. However, this assumption disregards the "double bind," in other words, the way in which race/ethnicity and gender function *simultaneously* to produce distinct experiences for women of color in STEM. A dedicated research base about women of color would help assess the root causes of attrition, retention, or advancement for this population; to identify and remedy gaps in the research; and to broadly examine and improve upon programmatic, institutional, and nationwide efforts.

The NSF-funded project *Inside the Double Bind: A Synthesis of Empirical Research on Women of Color in Science, Technology, Engineering, and Mathematics* (Ong et al.,

2010) sought to fill the gap in the knowledge base by synthesizing 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 which factors promote success[6] for women of color in STEM. Between 2006 and 2009, the project's team of researchers systematically searched for, identified, compiled, and synthesized empirical research on the postsecondary and career experiences of women of color in STEM, produced between 1970 and 2008. One result is this article: the first published synthesis of its kind on empirical research on the higher education experiences of women of color in STEM. This paper makes a unique contribution to the field by presenting a compilation of nearly 40 years of findings on the variety of factors that play significant roles in the persistence or loss of underrepresented minority women in STEM at the undergraduate and graduate levels; it also offers researchers a comprehensive agenda for expanding the literature moving forward.

This article is divided into two primary sections. Following the methods section, we discuss findings from the literature first about undergraduate life and then about graduate school experiences. These life stages are treated separately. We considered conducting our analysis of the literature in a number of ways, including by theme (family, mentoring, etc.); discipline (physics, biology, etc.); major field (physical sciences, biological sciences, etc.); fine life stage (lower division or upper division undergraduate, master's, doctoral); or major life stage (undergraduate, graduate). Examining findings by undergraduate and graduate levels most closely reflected the categorizations commonly found in a majority of the empirical research documents. Furthermore, we identified too many gaps in the existing literature to conceptually analyze racial and ethnic subgroup experiences among women of color and create a coherent picture of student experiences.

In the undergraduate section, we challenge a prevailing notion that STEM educational attainment among women of color lags behind that of their White female and minority male counterparts due to these young women's lack of interest in STEM fields. By presenting a synthesis of empirical research on the structural environments in STEM at undergraduate institutions, and how minority women negotiate such environments, we demonstrate the complex and layered factors that influence their retention and achievement at the baccalaureate level. We present these specific factors that include STEM enrichment programs, personal relationships and influences (faculty, peers, and family), a sense of academic self, individual agency and drive, and the overall climate in STEM learning environments for women of color.

The graduate section highlights the first few years of graduate school as a critical point of loss of women of color from STEM fields and reviews factors shown in the literature that help or hinder them as they attempt to complete their degrees. Discussed in more detail are funding issues, mentorship and role models, faculty influences, graduate training and networking, family sup-

port, outreach, and the STEM climate. We pay special attention to the baccalaureate origins of STEM graduate students, which appear to be an influential factor in PhD attainment, and to the informal, rather than structural, elements of graduate education that can be significant hurdles for women and minority students.

In closing, we discuss the policy implications of these findings and highlight aforementioned gaps in the literature where further research and evaluation are greatly needed. It is our hope that this article will motivate new and established researchers to build a larger body of empirical studies that will prompt ongoing awareness and discussion of the need to address the experiences of women of color in STEM.

Method

Data Collection Sources and Methods

The *Inside the Double Bind* synthesis project was cross-disciplinary, delving into empirical research from across the social sciences and STEM disciplines, particularly reports and papers coming out of, and directed toward, the STEM community. The project team conducted an extensive literature search on multiple levels of STEM education and careers: undergraduate, graduate, postdoctoral, early entry, midcareer, and leadership career positions as well as the broader notion of education and career pathways in STEM.

We conducted searches of forty-eight electronic databases, clearinghouses, dissertation indexes, and Internet search engines. We also sent out more than 125 calls to national conferences, listservs, and special interest groups working in areas of gender/sex, culture, race/ethnicity, and STEM. Furthermore, we sent direct inquiries to STEM organizations, journal editors, and researchers identified as working on the topic of women of color in STEM.

The data collection process resulted in 634 documents. Our team focused on filtering these documents according to stricter parameters: only empirical works[7] that specifically addressed the status and/or experiences of U.S.-born women of color since 1970 comprised the final pool of literature for analysis. The filtering process yielded 116 empirical research documents. Empirical studies on students (92) dominated our findings, followed by studies on STEM professionals (24) and faculty (15). The tables summarize other key features of the empirical documents identified.

The works we identified occasionally focused on members of a single race/ethnicity, but more often they used comparative approaches that included women of different races/ethnicities (including White women), men of the same race/ethnicity, and/or White men. Ninety of the works we identified included findings from undergraduate and graduate life stages of women of color in STEM (see table 2 for a breakdown by field of study). The remaining twenty-six documents presented findings from the career level only, which are not within the purview of this paper.[8]

TABLE 1 *Characteristics by race/ethnicity*

Race and Ethnicity	*Number of Documents*
African American	98
Chicana/Latina	67
Asian American / Pacific Islander	45
Native American	43

Note: Columns do not add up to total count of 116 since there may be more than one race/ethnicity per document.

TABLE 2 *Characteristics by field and life stage*

Field	*Undergraduate*	*Graduate*
Life science	2	1
Physical science	7	3
Mathematics	13	2
General science	23	11
Computer science/technology	10	6
Engineering	19	12
STEM	19	5
Total	93	40

Note: Columns do not total 90 because there may be more than one life stage represented per document.

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Coding and Analysis

Eight team members developed codes using concepts identified in existing theory (Maxwell, 1996) and inductive categories using an open-coding technique (Glaser & Strauss, 1967; Strauss & Corbin, 1998). Taking a small but varied sample of the literature, we iteratively tested codes for validity and reliability.[9] Our final codebook consisted of more than one hundred codes. We then systematically coded all the documents.

We tracked the study designs and research methods used in each of the 116 empirical studies. Of the total studies, 39 employed qualitative methods (ethnographies, case studies, interviews, and phenomenological studies); 67 employed quantitative methods (descriptive, experimental, quasi-experimental studies); and ten used mixed methods. A full description of our data collection, organization, and coding methods, including our analyses and plans for dissemination, is in our technical report (Wright & Ong, 2010).[10]

Limitations of the Study

Our searches were thorough but not exhaustive. We did not include materials on K–12 education, professional schools (e.g., medical, veterinary), foreign

school and employment systems, and congressional hearings. In addition, we determined investigating and explaining immigration concerns related to foreign-born (non-U.S.) students and scientists to be beyond the scope of this project. With the intention to contribute to the knowledge base on how the United States can excel in creating a domestically grown scientific workforce, we filtered out studies on foreign-born women of color studying and/or working in the United States.[11]

It is important to note that these studies vary widely in terms of the number of participants, methodological rigor, length, and quality of writing. An assessment of the methodological rigor of each study was beyond the scope of this paper. Some empirical works by the same author report on the same research; in these cases, we chose to cite all the relevant studies. Lastly, the limitations of the original research we reported on include small sample sizes, a lack of research using advanced statistical analyses, a dearth of longitudinal quantitative studies with robust, national datasets, and far more studies on African American women than on women of other racial/ethnic backgrounds. We discuss these limitations more fully in the body of the paper.

On Terminology

The racial/ethnic terms utilized in this study often correspond to the categories used by data collection and reporting 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, we use the terms Black and *African American* interchangeably, as we do *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, we use the terms *women of color* and *minority women* 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, 2009).[12] Although Asian American women may 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 (NSF, 2007; Nelson & Rogers, 2004). Consideration of Asian American women's status and experience 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).

Overall, our analytic process yielded both a unique bibliography of empirical works on the understudied population of women of color in STEM as well as the following findings about common elements at the undergraduate and graduate life stages that greatly affect their advancement in STEM disciplines.

The Undergraduate Experiences of Women of Color in STEM

The talent pool of women of color in STEM has widened in recent years, 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, an aforementioned 2006 national review of population statistics and STEM baccalaureate degrees reveals differential attainment by URM women as compared to their White female peers (see figure 1). Further, despite outperforming their male counterparts 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). Furthermore, women of color experience these fields quite differently from URM men and White women (N. W. Brown, 1997; Varma & Hahn, 2007).

The pernicious myth that women of color are underrepresented in STEM fields because they are simply not interested in pursuing scientific careers continues to circulate. However, research shows that underrepresented minority women are just as likely as their White peers to intend to pursue an undergraduate STEM degree (Bonous-Hammarth, 2000; Chipman & Thomas, 1987; Ethington & Wolfle, 1988; Hanson, 2004; Huang, Taddese, Walter, & Peng, 2000; Smyth & McArdle, 2004; Staniec, 2004). These studies reveal a disturbing trend—despite great interest by women of color to pursue STEM baccalaureate degrees, this group nonetheless remains underrepresented in degree completion.

Many scholars (Carlone & Johnson, 2007; Hanson, 1996, 2004; Justin-Johnson, 2004; Ong, 2005; Vogt, 2005) attribute this attrition of women of color from STEM fields to educational and occupational institutions' failure to fully develop science talent. They point to the social and structural environment of college as the main source of women of color's attrition in undergraduate STEM education. Here, we specifically address the college experiences of women of color in undergraduate STEM education through the synthesis of research on the structural environments of undergraduate institutions and the ways in which women of color navigate the STEM environment, including the importance of enrichment programs and the role of influential individu-

als and groups in women's lives. Our analysis reveals that the myriad of factors discussed later—including the STEM climate in undergraduate learning environments, STEM enrichment programs, relationships, and self-concept—influence women's identities and actions in pursuit of STEM degrees.

The STEM Climate at the Intersection of Gender and Race/Ethnicity

Many of the studies we found highlighted measures of the STEM climate as central to the experience of women of color pursuing undergraduate STEM majors. Theoretical discussions of climate—often described as "chilly"—addressed evidence that women were treated differently from men by science faculty and peers (see Crawford & MacLeod, 1990). Yet the inclusion of racial and ethnic discrimination presents an ever more complicated environment for women of color. Several studies specifically demonstrated 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 (Carlone & Johnson, 2007; Justin-Johnson, 2004; Ong, 2002; Sosnowski, 2002; Valenzuela, 2006).

Carlone and Johnson's (2007) conceptual model, which is based on a six-year ethnographic study of women of color STEM majors at a predominantly White institution (PWI), characterizes the identity development of women of color within a setting that often contradicts their unique vantage point. The researchers' model emphasizes the need for women of color to feel recognized as legitimate members of the STEM community while noting that such recognition is often elusive.

> 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 & 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). The work of D. Johnson (2007) on the relationship between racial climate and the sense of belonging for women of color in STEM reinforces such findings. In this study, a lack of African American peers in science departments led to feelings of segregation, which often affected women's racial/ethnic and cultural identities.

Other studies in our data illustrate a supportive climate for women in STEM, particularly at historically Black colleges and universities (HBCUs) (Giguette, Lopez, & Schulte, 2006; Lent et al., 2005; Whitten, Foster, & Duncombe, 2003; Whitten et al., 2004). Key features of these environments were openness toward alternative routes into the major, a lack of stigma for reme-

dial course work, high expectations for student success, and a supportive and healthy relationship between students and faculty. Although several studies have examined 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 they pertain to the collegiate experiences of women of color in STEM.

The culture of STEM departments is another important consideration, in that they include a structure that is supposedly meritocratic in nature and focus on grades, classroom performance, and research results, which 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 that

> 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. (p. 43)

This and other studies address 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 (see Dickey, 1996; Varma, Prasad, & Kapur, 2006). A young woman in Dickey's (1996) study, who was the only minority woman in her laboratory, said, "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 this 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). While in and of itself damaging to a woman's sense of self, such unsupportive climates can further lead to social stratification and low expectations of minority women (see Chinn, 1999).

In addition to the overarching campus experience, research has demonstrated that classroom interactions are also critical in determining STEM persistence or attrition for undergraduates of all backgrounds. The literature on women of color furthers this 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 the highly valued activity of classroom participation (A. Johnson, 2005). Addressing the affects of institutional type, Valenzuela (2006) studied Chicana/Latina math and science majors who transferred from community

colleges to large research universities. On transferring, women experienced a profound shift in classroom diversity and culture. According to Valenzuela, the women in her study found community college classrooms to be racially/ethnically diverse and collaborative. In contrast, at the university level, women experienced less classroom diversity and a lack of peer support due to an emphasis on individualized learning and 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-age populations, so it is little surprise that women of color also benefit from their offerings. Most common in the literature were reports on the positive (as well as negative) experiences of women of color in undergraduate research assistant positions (Dickey, 1996; A. Johnson, 2007). Minority women were often the only researchers of their gender and race/ethnicity in their laboratories or research groups (A. Johnson, 2007; 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). Espinosa's (2009) study shows the undergraduate research program experience as positively related to the overall persistence of women of color in STEM majors.

When considering STEM retention programs (those with and without undergraduate research components), findings generally support a positive programmatic impact on a number of student experience dimensions (S. W. Brown, 2000, 2002; Ellington, 2006; Heller & Martin, 1994; Meiners & Fuller, 2004). Through her ethnographic study of women of color in physics at a PWI, Ong (2002, 2005) learned that recruitment and retention programs chiefly serving women or minorities in physics provided critical safe spaces for URM women to: (1) belong to a supportive community of scholars who looked like them; (2) reject negative stereotypes; (3) validate their identities as emergent scientists; (4) learn how to address microaggressions (subtle offenses) from faculty and peers; and (5) grow their subcommunity by serving as role models, mentors, and teachers (Ong, 2002, pp. 115–116).

Nave, Frizell, Obiomon, Cui, and Perkins (2006) examined the academic performance and graduation rates of women who were part of the NSF-sponsored STEM-Enrichment Program (STEM-EP) at an HBCU. They found that this group did better academically (as measured by grade point average) in first-year course work than their male peers. At community colleges, Chicana and Latina women found academic, personal, and social support from the Mathematics, Engineering, Science Achievement (MESA) program (Valenzuela, 2006). In all, the high academic expectations set forth by retention programs and program staff—and the cohesive peer community these programs foster—have been shown to be critical in supporting student persistence (Ellington, 2006; A. Johnson, 2005).

Relationships and Influences

Research suggests that women of color seek out academic and personal support vigorously and with serious intent. These relationships serve to bolster their confidence and learning in STEM majors as well as their determination to graduate. Women of color tap into a host of networks that include parents, faculty members, university administrators, and peers in- and outside STEM fields. 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. Chicana/Latina transfer students attending PWIs sought out tutoring, student groups, and other campus resources to create support systems that helped them succeed as young scientists (Valenzuela, 2006). Finally, Fuller and Meiners (2005) found that women of color valued university settings where they could contribute to the community at large, as these activities provided them with support and encouragement to succeed.

Interestingly, among the various sources of support that young women of color tapped into, it was not necessarily the case that their role models and peers were of shared gender and racial/ethnic backgrounds. Perhaps given the overwhelmingly male-dominant atmosphere of engineering, the African American women in Shain's (2002) study indicated that while their cultural identity was important to their educational experience overall, the cultural background of their key support person in the major was not a factor. Thus, women of color may make personal adjustments to suit the culture of their chosen discipline, such as seeking mentors outside their gender and/or racial/ethnic group (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 as serious students by their professors (Carlone & Johnson, 2007; S. W. 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 A. Johnson's (2007) study, given the sheer importance that minority women 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. In Espinosa's (2009) dissertation study, women of color who switched out of STEM had more interaction with professors than those who stayed in STEM majors.

On the contrary, Ellington (2006) and Dickey (1996) reported that women of color viewed professors as instrumental in making a STEM career a real possibility, a positive 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 to long-term student success, particularly given 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; Grandy, 1998; Guevara, 2007; Hall, 1981; Tate & Linn, 2005) but also touched on 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 looked outside of STEM but within their racial or ethnic community to build peer support. Shain (2002) noted 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).

Family and Community

Family and community support is perhaps the most salient and influential factor that women of color identify as encouraging to their completion of a STEM degree (Andrade, 2007; Bellisari, 1991; S. V. 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 women scientists in their study: encouragement, acceptance, and educational expectations (p. 707). Other studies further emphasized 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 and parental education level (Brown & Cross, 1997; Trenor, Yu, Waight, Zerda, & Sha, 2008).

Familial support, 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, and they also faced 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 seem particularly salient for students from Chicana/Latina backgrounds (Valenzuela, 2006). Families expected the Native American women in Varma and Galindo-Sanchez's (2006) to manage the family structure, while the African

American women in Chowdury and Chowdury's (2007) study reported the absence of familial support for their engineering studies. Studies found that parental pressure promoted 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 when choosing a major 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 stresses 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 families and communities 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)

The impact of positive pressure is found in another body of work that looks at why women of color choose STEM majors. Carlone and Johnson's (2007) study identified a cohort of women who pursued science as "a vehicle for altruistic ambitions" (p. 1199). Utilizing this framework, Espinosa (2009) found that women of color who placed personal importance on making a theoretical contribution to science or finding a cure to a health problem were more likely to persist to the fourth year of undergraduate study in STEM.

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 their academic abilities (Brownlee, 2004; Espinosa, 2008; Hackett, Casas, Betz, & Rocha-Singh, 1992; 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. She 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 a student's 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 at college entry.

Self-efficacy and academic confidence have further been explored in relation to STEM entry. Gwilliam and Betz (2001) determined that a strong rela-

tionship exists between science self-efficacy and the choice of a scientific major for African American women. Further, Maple and Stage (1991) found that the attitudes African American women held toward their math ability directly affected STEM major choices. Specifically, self-confidence has been shown to be an important factor in the academic success of African American female engineering majors (Shain, 2002).

Personal Agency and Drive

Ellington (2006) has shown that the personal agency and drive of women of color develop greatly during the undergraduate years. Varma (2002) found that the Hispanic females in her study of computer science/engineering women attending a minority-serving institution (MSI) were often determined to achieve their bachelor's degree by means 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/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 relates to how students tap into their racial/ethnic and cultural identities. Despite marginalization, women of color often use their status as a member of two underrepresented groups—as a woman and as a person of color—to empower themselves (Carlone & Johnson, 2007; Ellington, 2006; Ong, 2002, 2005), which ties directly to the ways in which students understand and handle racism and to their subsequent ability to navigate the STEM environment (Shain, 2002). For example, Hanson (2004) pointed to the construction of gender in the African American community as being congruent—and not at odds—with the 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 and negative gender stereotypes (see Gonzales, Blanton, & Williams, 2002). 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 stereotypes. 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.

The interplay of structural systems, individual and group influences, and self-concept revealed in the literature points to a complex array of issues at

work in minority women's ability to thrive or fail in STEM undergraduate education. Arguments that point to a lack of interest or ability among women of color to achieve in STEM to explain their underrepresentation in these fields grossly oversimplify the reality of these students' experiences. For those women who complete their baccalaureate degrees and enter STEM graduate programs, many of the challenges of undergraduate school persist through the next life stage. For example, racial/ethnic microaggressions, stereotyping, peer and faculty relationships, and family expectations all exist at the undergraduate as well as graduate levels. At the same time, they face challenges unique to the graduate school environment as they adjust to the rigors of STEM graduate-level studies and become acculturated to their individual disciplines.

The Graduate Experience of Women of Color in STEM

The successful completion of a STEM baccalaureate degree can lead women of color to new opportunities and challenges in the graduate school context. S. V. Brown (2000) identifies the transition from college to graduate school as a "strategic point of loss" (p. 247) of minority students from STEM education. The loss is one that particularly affects women of color, who are growing in numbers on college campuses and are earning more bachelor's degrees relative to their male counterparts in almost every STEM discipline. Yet, while minority women have the requisite degrees for entrance to graduate school in STEM fields, they earn fewer PhDs relative to their minority male, White male, and White female peers (NSF, 2007). 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 PhDs, the recruitment and retention of women of color in graduate school is of paramount importance for diversifying the nation's faculty.

This section offers a synthesis of findings on the graduate school experiences of women of color in STEM, including transitions from college to graduate school, funding, social climate, mentorship and role models, faculty influence and support, graduate training and networking, family influence and support, and outreach. In particular, we highlight the informal, nonacademic elements of these students' experiences, which several scholars have argued may hinder women and minorities more than any other component of the graduate school experience (S. V. Brown, 1995, 2000; Hall, 1981; Malcom et al., 1976; Ong, 2002, 2005). How well these challenges are met can play a determining role in students' options and choices for postdoctoral programs as well as for their subsequent careers (MacLachlan, 2006). Where graduate students receive prior training also appears to play a key role in their ability to persist in their programs; thus, we also present studies that provided data on the baccalaureate origins of women of color STEM.

Baccalaureate Origins and Graduate-Level Parity

Some schools do better than others at producing STEM bachelor degree recipients who achieve doctorates. Research shows that many of these schools are MSIs (Leggon & Pearson, 1997; Solórzano, 1994, 1995). Despite the successes of these schools, data (though in need of updating) show that the gap in representation between women of color STEM students and their White/male counterparts is so significant that achieving parity would require drastic, more widespread change. For example, Solórzano (1994, 1995) conducted secondary analyses of quantitative data from the National Research Council's (NRC) Doctorate Records Project (DRP), focusing on the baccalaureate origins of African American and Chicana[13] PhD recipients between 1980 and 1990 in physical, life, and engineering sciences. He found that, in comparison to the percentage of their national age cohort, Chicanas were severely underrepresented in these fields and concluded that it would take a tremendous increase in production—"anywhere from 6- to 17-fold" (1994, p. 259)—for Chicanas to reach parity with their overall U.S. population in these three STEM fields. He also determined that to reach parity with their general U.S. representation, African Americans'—both women's and men's—doctorate production would need to increase from 500 percent to 1,100 percent in certain disciplinary fields (1995, p. 19).

Burrelli's (2009) recent findings show that, between 2003 and 2007, four of the five highest producers of Hispanic female STEM bachelor's degree recipients—University of Puerto Rico Mayaguez, University of Puerto Rico Rio Piedras, Florida International University, and California State University Northridge—are HSIs. This shows a shift in trends from Solórzano's (1994) study, which reported that, between 1980 and 1990, Chicana science doctorates were less inclined to begin their educational careers at HSIs; instead, they tended to come out of large, comprehensive research universities. Solórzano (1994) indicated that only nine institutions produced three or more Chicana baccalaureate recipients who went on to receive doctorates in STEM and that two HSIs produced 20 percent of Chicanas who continued on to receive science doctorates.

Solórzano (1995) also reported that, between 1980 and 1990, thirty out of the top-fifty undergraduate institutions that produced African American female doctoral recipients in science and engineering were HBCUs. Furthermore, when controlling for the size of these institutions, he found small colleges to be more productive than large universities in producing African American doctorate recipients. Leggon and Pearson (1997) studied the baccalaureate origins of 1,465 African American female PhD recipients in the general fields of biological sciences, physical sciences, and social sciences from an NRC dataset for African American science doctoral recipients between 1975 and 1992. While their findings resonated with Solórzano's (1995), their analysis included a closer examination of the effects of HBCUs, small institutions,

and women's colleges. They concluded that HBCUs and women's colleges produced a disproportionate number of African American female PhDs in the biological and physical sciences because of their deliberate efforts to establish an 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, such as those offering summer research experiences.

Very little empirical research exists about the parity status or baccalaureate origins of Native American, Chicana/Latina, and Asian American female graduate students. Chipman and Thomas (1987) provided a snapshot of these groups' "representation ratios" using U.S. Office of Civil Rights data on master's and doctoral degree attainment 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. Perhaps not surprisingly, with the exception of Asian American master's degree recipients, women of color were below parity in every category.

Transitions from STEM Undergraduate Programs to Graduate Programs

The empirical literature suggests that there is a disconnect between at least one undergraduate environment where women of color in STEM seem to thrive—MSIs—and the graduate programs where they later enroll. Joseph (2007) studied six African American women transitioning from HBCU undergraduate programs to mathematics and chemistry doctoral programs at PWIs. She found that undergraduate years at HBCUs were mostly "filled with encouragement and support" (p. 194) by administrators, faculty, staff, and peers. In contrast, in their graduate programs at PWIs, they encountered academic difficulties and experienced social isolation in their departments: "meeting people and finding their place in the department was difficult" (p. 195). One chemistry graduate student told Joseph, "I feel most of the time that I am so different from everyone here and really alone" (p. 116). MacLachlan (2006) studied women of color scientists who received their doctorates from the University of California. She, too, found that a subset of African American women in the study who had attended HBCUs as undergraduates reported academic and social difficulties in their transition to PWIs (p. 239).

In their survey study of 290 physical science and engineering graduate students' Graduate Record Examination (GRE) scores and attitudes in the Midwest, Santiago and Einarson (1998) found that U.S. minority women were "at a particular disadvantage relative to their nonminority peers" in terms of their scores (p. 173). Nevertheless, 43 percent of minority women felt their gender was an asset (compared to 60 percent of White women), and over half of the minority women reported that they felt their race/ethnicity was an asset. In another survey study of fifty-two minority women STEM professionals, respondents recommended better undergraduate training, facilitating student mem-

berships to undergraduate honor societies, providing information about graduate departments, and enacting more aggressive efforts to identify and enroll minority students (Hall, 1981).

Funding Issues

The 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. In her study on minority women in engineering, Sosnowski (2002) noted that "finding access to and negotiating the requirements and paperwork is often a major stumbling block to fund the cost of tuition and maintaining enrollment" (p. 64). When Hall (1981) surveyed minority women professionals in STEM fields about what they would recommend to retain young women of color in graduate STEM programs, the most common response was to increase financial aid. Sosnowski (2002) and Hall (1981) recommended that undergraduate and graduate programs make transparent the availability of funding for graduate school and provide guidance in navigating the processes of applying for these funds. However, knowledge about applications and winning fellowships may not be enough. S. V. Brown's (1995) research on scoring patterns of applications for the prestigious NSF fellowships revealed that, relative to other applicants, "minority women are significantly less likely to receive high panel rating averages . . . or to receive offers of fellowships" even when factors such as undergraduate grade point average are controlled (p. 259). Even in cases where they *do* receive fellowships, S. V. Brown (1995) found that they are significantly less likely to complete their degree requirements compared to their White and male counterparts.

The STEM Climate

The existing empirical work on graduate experiences overwhelmingly identifies the STEM social and cultural climate—that is, the interpersonal relationships with other members of the local STEM communities and the cultural beliefs and practices within STEM that govern those relationships—as the leading challenge to the persistence of women of color in STEM career trajectories. A large survey study of minority women in STEM graduate programs (S. V. Brown, 1994, 2000) revealed that the nature of "interpersonal relations"—including isolation, racism, sexism, being racially/ethnically identifiable, and relationships with faculty and other peers—caused more difficulty for women of color than structural barriers such as financial aid, recruitment practices, composition of the faculty body, tutorial and counseling support, and teaching or research assistantships. S. V. Brown (2000), Joseph (2007), and MacLachlan (2006) found that the prevalent cultural belief in White male superiority, especially in the realm of STEM fields, played out as microaggressions in the everyday practices of graduate programs, affecting the experiences of the minority women in their respective studies. The participants frequently

reported feeling negatively judged by their (usually male) peers as intellectually inferior, and such judgments often resulted in their social isolation and inability to join study groups. S. V. Brown (2000) reported that "White students were often described as arrogant and indifferent, while minority men were said to treat minority women as intellectual inferiors" (p. 259). According to MacLachlan (2006), minority women in her study felt "surveilled" by their peers, and "problems with racism and sexism tended to originate with male student colleagues" (p. 241).

Additionally, Joseph (2007) found that the African American women in her study transitioning from HBCU undergraduate programs to PWI graduate programs, who were usually the *only* women of color in their respective departments, had difficulty meeting people and cultivating a sense of belonging in the department. To cope with these stresses, the students in Joseph's study often "fragmented" their identities (Lugones, 1994; Ong, 2002, 2005), revealing only a portion of their selves (i.e., their scientist identities) to their departmental colleagues while sharing other parts (i.e., social identities) in other contexts, such as in meetings of the Association for the Concerns of African-American Graduate Students. For example, one mathematics graduate student said, "I have . . . changed my mode of thinking and concentrate on math and math only" (Joseph, 2007, p. 91). Ong (2005) similarly found instances of fragmentation in her longitudinal study of four women of color graduate students in physics. One self-described Chicana student conscientiously wore drab clothing to work (reserving her pink wardrobe for events that did not include labmates), while a fellow Latina student spoke of how, for the purposes of seeming confident when talking with physics peers, she had to "un-learn" prefacing her comments with phrases like "I think" or "I am not sure, but . . ." (Ong, 2005, pp. 605–606). Students in both Joseph's and Ong's studies spent a lot of time and energy changing how they dressed, spoke, and presented themselves to others—partially masking their gendered or raced selves—in order to gain acceptance within their STEM communities.

Mentorship and Role Models

Mentorship, formal or informal, is often cited as a vital element in promoting women of color in nontraditional fields (e.g., Burlew & Johnson, 1992; Hall, 1981; Ong, 2002; Sader, 2007). For women of color doctoral students in STEM, their mentors often play important roles in their decisions to attend graduate school, choose a particular doctoral program, and/or stay or leave their programs. The mentoring role can be occupied by a variety of people, including family members, peers, former or current employers, and former or current teachers (Hall, 1981; Ong, 2002; Sader, 2007). Our synthesis revealed that mentoring by faculty, in particular, was rare but incredibly valuable. According to S. V. Brown (2000), "few minority women had true mentors while in graduate school, but those who did reported exceptional relationships and experiences" (p. 259). Because of the current demographic makeup

of STEM, more often than not these mentors have been male and White. One minority woman scientist in MacLachlan's (2006) study said that she gained "a lot of independence, self-reliance" and "confidence" from her mentor, and another said that her graduate mentor "gave me training that allowed me to succeed and be professional" (p. 240). A student in Joseph's (2007) study said her minority male mentor advised her to "become visible in the department" (which she did as the department's speaker events coordinator) and that she should maintain a "strong distinction between her role as a graduate student and her personal interests" (p. 90). In following her mentor's advice, the student reported that she was better able to cope with social isolation and persist in her graduate studies.

Our synthesis study identified only one scholar, S. V. Brown (1994, 2000), whose research addressed the effect of the presence or absence of role models on women of color's experiences in STEM at the graduate level. The author reported a survey 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, especially in physical sciences and engineering, was a disadvantage to them.

Faculty Influences and Support

Unfortunately, strong mentoring relationships with faculty, as critical as they might be, are very rare (S. V. Brown, 1994, 2000; Hall, 1981; MacLachlan, 2006). Our synthesis revealed a number of studies on cultural bias against women and/or minorities that played a significant role in undermining the success of women of color in STEM. S. V. Brown (1995) found that, in rating NSF fellowship applicants, faculty systematically gave lower assessments of minority women relative to those of their White and male counterparts; this finding held *even when undergraduate GPA and degree field majors were considered.* Solórzano (1994, 1995) 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 PhD programs with the distinct disadvantage of lowered expectations from professors. Carlone and Johnson (2007) and MacLachlan (2006) reported that women of color received subtle cues from faculty about their perceived token and inferior status. According to MacLachlan (2006),

> [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)

Findings about poor levels of support from faculty point to the urgency of more women of color completing STEM graduate programs. Graduate degree acquisition feeds into faculty populations. One of the key factors in the suc-

cessful integration of public schools and colleges during the civil rights era was the desegregation of faculties (*Green v. County School Board of New Kent County*, 1968).[14] Similarly, creating more women of color STEM PhDs and getting them into faculty positions could help foster cultural changes that would improve overall faculty support for and increase the enrollment and retention of minority women.

Graduate Training and Networking

Two works in our synthesis study address graduate-level training and networking. Hall's (1981) survey study of professional minority women in STEM includes a section soliciting suggestions to retain women of color in graduate school. Respondents stressed the need for the inclusion of women of color in programs that provide work experience in industry, high-quality research training, and the development of formal and informal professional networks. Joseph's (2007) study supports the importance of these networks; one participant in her study, an active member of the campuswide Association for the Concerns of African-American Graduate Students, stressed that networks of culturally similar graduate students provide "a great way to connect with others who understand what you go through on a daily basis in some form or fashion" (pp. 99–100).

Family Influence and Support

Only a few empirical works on women of color graduate students in STEM cite the importance of family influence and support. MacLachlan (2006) and Sosnowski (2002) found evidence that family members, including those without any STEM background, provided strong support networks and reinforced values that helped to sustain minority women in STEM. For instance, Sosnowski (2002) describes how an African American female doctoral student credited the principles she learned while growing up in a strong, religious family with the resilience and 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).

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 to promote their careers in STEM; mothers, especially, often provide young women with "more liberal sex-role attitudes" that encourage them to pursue studies and careers in nontraditional fields like STEM (p. 163).

Outreach

A common finding across empirical research on women of color in graduate STEM programs is that the students were active, or planned on being active, in reaching out to other women—younger students and fellow women of col-

or—to draw them into and retain them in STEM fields. For example, participants in Joseph's (2007), Sader's (2007), and Sosnowski's (2002) respective research reported career aspirations as educators so that they could mentor and serve as role models to younger generations of women of color. Sosnowski said of one African American engineering doctoral student:

> Grace believes in being a role model . . . for those coming up the ranks in engineering. She knows just how important it is to encourage younger women of color to fields in STEM. 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)

Ong's (2005) longitudinal, qualitative study describes one African American doctoral candidate in business and science who, despite being overcommitted because of her studies and her time spent trying to start a new business, kept active as a leader in the student government, with her main activities related to recruiting underrepresented students to her predominantly White graduate school. Examples of recruitment included calling prospective minority students who had been accepted to the program and organizing receptions with other underrepresented students if they visited the campus. 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" (p. 608). Similarly, a Latina student in Ong's (2005) study spent a year organizing and implementing fun science lessons for predominantly minority elementary school children in an urban school district.

Not only does this review of the literature reveal the complexities of the journey to PhD attainment for women of color, but it also shows how little we know of their experiences. We found only a small number of empirical documents on the graduate experience of this population: forty produced in forty years.

Conclusion and Recommendations

The *Inside the Double Bind* (Ong et al., 2010) synthesis study identified several characteristics common 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 MSIs to PWIs; the critical role that climate plays in women's satisfaction and retention in STEM, including issues of isolation, identity, invisibility, negotiating/navigation, microaggressions, sense of belonging, and tokenism; and the positive and negative effects of words and actions by faculty, peers, and family members. We highlighted discussions of the significance of funding opportunities and networking and professional training solely in our findings about graduate students. Likewise, we discussed

STEM enrichment programs and students' academic sense of self and personal agency as having an impact only in findings about undergraduate students. We do not claim that any of these factors is unique to either life stage, only that too little research on these themes exists to claim them as common factors across undergraduate and graduate experiences. They represent only a few of the significant gaps in the literature identified through the process of creating this synthesis.

Empirical research on women of color in STEM at the undergraduate and graduate levels has certainly come a long way since the publication of *The Double Bind* (Malcom et al., 1976): over half of the studies collected for this project, *Inside the Double Bind,* were conducted or published since the year 2000. While it is promising that researchers are taking greater notice of the need to address the intersection of gender and race/ethnicity in STEM education and careers, there is a long way to go before we can truly understand the environments and experiences that promote or hinder the advancement of women of color in scientific and technical fields.

Research on issues and populations considered low priority is often not funded, and basic data are not collected or reported (Ong, 2010). Such negligence can create a vicious cycle of invisibility of existing injustices and inequalities that undermines arguments for reform. By making women of color in STEM a high-priority research area, we can stimulate better data collection and analysis that will foster a *virtuous cycle* that grows understanding and encourages serious discussion of reform. Toward this goal, this final section outlines a recommended research agenda, including cross-cutting research foci and those specific to the undergraduate and graduate trajectories, along with policy implications for broadening the current and future participation of women of color in STEM fields.

Cross-Cutting Research Gaps

Our synthesis revealed a number of research gaps that span disciplines, races/ethnicities, and life stages. 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 across multiple life stages (K–12, undergraduate, graduate, postdoctoral, career). Advanced statistical analyses, beyond descriptive accounts, on these datasets and others are essential. Additionally, an updated survey of women of color professionals, like that of Hall (1981), addressing the long-term impact of undergraduate and graduate experiences in STEM would complement a growing body of literature that follows women throughout the STEM pipeline. This growing research field also has an overarching need for theoretical and conceptual frameworks that address women of color in STEM as a stand-alone population.

Regarding specific subpopulations, research on African American women in science represents a substantial portion of the existing literature, albeit it

remains slim in quantity. In addition to further research on the undergraduate and graduate experiences of this group, we need to bring other racial/ethnic populations into the fold through increased study of Chicana/Latina, Native American, Asian American (particularly Southeast Asian and Pacific Islander), and multiracial women in STEM. Beyond racial/ethnic diversity is the need for studies inclusive of broader participation in terms of geography, socioeconomic status, and individual STEM disciplines.

Research into potentially serious infringements of civil rights may also be merited. Current discriminatory practices should be considered, as well the history of discrimination against minority women that may have continuing impacts on the patterns we see in their education today. Research by legal scholars and social scientists may illuminate these issues and aid in the construction of affirmative action policies and plans that will critically support women of color and other underrepresented groups.

A Research Agenda on Undergraduate Women of Color in STEM

Undergraduate education marks the first point of entry into the postsecondary pipeline and influences graduate school and career aspirations, making it essential to further explore how colleges and universities can best support women of color pursuing STEM majors. Existing scholarly contributions to understanding 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 too many.

Perhaps most salient to individual colleges and universities would be findings that support the need to address STEM pedagogy and curriculum for diverse populations as well as research on the relationship between pedagogical changes and cognitive outcomes for women of color. There is need to further study campus-based resources, such as academic advising, that support pre–graduate school preparation. Also, the role of influential individuals, such as professors and peers, needs further exploration. Specifically, the role of mentoring for women of color in formal and informal settings in- and outside of organized STEM retention programs remains to be examined.

Finally, the impact of unique institutional environments needs to be better understood. For example, there are very few studies that address the experiences of women of color in the academic and social environments of HBCUs and HSIs; none addresses this topic at TCUs. Likewise, two-year institutions and community colleges are important STEM education pathways for many women of color, yet their experiences in these environments, their transitions to four-year schools, and the impact of articulation agreements are largely ignored in the literature. Since we know that many women of color students reflect nontraditional profiles (e.g., as older students or students with families), their nontraditional trajectories through STEM undergraduate education (e.g., attending part time, stopping-out) merit study.

A Research Agenda on Graduate Women of Color in STEM

While there was some research on women of color in STEM at the graduate level conducted between 1970 and 2008, we found significantly fewer studies about this population's experiences compared with those of undergraduates. We identified a large number of gaps in the literature. Some studies performed a decade or more ago, such as the quantitative parity studies (Leggon & Pearson, 1997; Solórzano, 1994, 1995), are in need of updating to reflect current trends. In addition, our searches did not reveal a single empirical study about women of color postdoctoral fellows.

Future scholars are encouraged to conduct more studies on institutional characteristics and environments. Recommended topics include the influences of funding (increasing costs of tuition, availability of fellowships and grants, etc.); the effects of recruitment and retention programs and other diversity programs; nontraditional pathways through graduate programs; types and effects of mentoring practices and of the presence or absence of role models; and the impacts of social climate issues and implicit bias. Also missing from the current literature are descriptions of successful institutional or programmatic interventions that make STEM departments feel more inclusive and research about the impact of networking, professional development, and outreach on career aspirations and attainment in STEM.

In addition, transitions from the undergraduate level to graduate school in STEM for women of color require special attention, as they represent a significant drop in retention. Both quantitative and qualitative studies are needed. Specifically, researchers need to conduct updated, large-scale studies on parity status and baccalaureate origins[15] of women of color in STEM by each racial/ethnic group that include the 1990s and early twenty-first-century data. Research also needs to be done on minority female students making transitions between undergraduate STEM training in MSIs and women's colleges to graduate training in PWIs.

Lastly, there needs to be more systematic and rigorous research on the influences of family on the experiences and advancement of women of color in STEM. Research should address the roles played by parents, siblings, extended family, spouses/partners, and/or children. Studies should extend to nontraditional families, including single-parent households and nonheterosexual partnerships. As many women are in graduate school during the years that are culturally considered peak childbearing years, studies should formally address family and education/career balance issues that are specific to women of color in STEM.

Policy Implications

Among the gaps in literature on women of color in STEM is the lack of national quantitative longitudinal studies. Central to education policy is the need to substantively address the intersection between gender and race/ethnicity in

both data collection and reporting. While much of the data and research on underserved students has focused on women and minorities, the vast majority of programming funded by federal agencies, such as the NSF and NIH, has supported these as *distinct* groups without purposefully addressing the intersection between gender and race/ethnicity. In addition to continued support of programs that help universities address the need for transformative structural change, there is a need for institutional-level policy that supports pipeline programs that begin in high school and extend through the early- and midcareer stages.

Since many women of color students represent nontraditional profiles, including collegiate entrance at the two-year level, it is absolutely critical that states have articulation and transfer policies—between two- and four-year institutions as well as across sectors and state lines—that support the mobility of today's students. Such support should include academic and social transition programming for women of color and aligned academic expectations by STEM faculty in two- and four-year programs. Once enrolled in STEM programs at either the undergraduate or graduate level, women of color should be provided the support to engage in rigorous research, benefit from student-faculty mentoring relationships, and access professional development and publishing opportunities—all of which only come from intentional institutional policy and practice designed to support the advancement of underserved populations in science and engineering.

While this article focuses solely on undergraduate and graduate experiences, we want to stress that women of color are lost at every transition point in the STEM pipeline. It is critical that state- and system-level policy support the academic alignment of K–12 and higher education systems and foster intradisciplinary understandings of what it means to prepare and educate STEM students for higher education institutions. As we move into an economic era requiring increased scientific expertise and technological literacy, sound public policy must support not only the educational pathways for women of color but also their transition into and sustainability within STEM careers. As a nation striving to keep hold of its innovative spirit and global position, the absence of women of color among the country's scientific leadership is a crucial opportunity missed.

While great strides have been made in empirical research over the past forty years (and especially 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 find ways to fully realize the potential of this great, untapped resource. It is our hope that this article provides a base of knowledge that will be greatly expanded in the future and that will be used by researchers, educators, scientists, civil rights groups, activists, and policy makers moving forward in their work of advancing women of color in STEM. America's scientific community cannot wait another forty years to uncover the next set of practical and political solutions to ensure the

entry and success of more women of color in STEM fields. We must utilize our collective knowledge base, continue to ask tough questions, and demand that meaningful steps be taken by policy makers and leadership within academe, government, and industry to ensure equal opportunity and support for all members of the STEM community.

Notes

1. For a more detailed explanation of racial/ethnic terms used in this paper, see the section, "On Terminology," p. 180.
2. White males made up 39.4 percent of the population in 2009. Their numbers had grown by 9.1 percent since 2000, compared to 10.5 percent for Black women, 18.0 percent for Native American women, and 36.3 percent for Latinas (U.S. Census Bureau, 2010).
3. The Latino population increased from 14.6 million in 1980 to 48.4 million in 2009 (U.S. Census Bureau, 2010). See also http://www.census.gov/population/www/socdemo/hispanic/files/Projections.csv
4. By 2007, 39.2 percent of the students in U.S. public schools were from underrepresented minority groups. The percentage has grown slightly each year since 1997, and women have been more likely to be enrolled than males (National Center for Education Statistics, 2009).
5. In terms of degree attainment of young adults, ages twenty-five to twenty-nine, in 2009, 15 percent of Latinas but only 10 percent of Latinos had BAs, as did 21 percent of African American women compared to 18 percent of African American men (College Board, 2010). The disproportion was much larger among new college students.
6. In this article, we define *success* as persistence in STEM.
7. For the purposes of our study, we define *empirical work* as work that presents a research question, research design, data collection and analysis, findings, and answers to the research question. Empirical works can employ qualitative, quantitative, or mixed methods.
8. Discussion of this study's findings on career experiences of women of color in STEM fields may be found in Ong et al. (2010).
9. We organized coding and data analysis into three life stages: undergraduate, graduate, and career. Within each life stage is a series of top-level codes and subcodes. For example, at the undergraduate life stage, top-level codes include student background characteristics and college experiences; subcodes include socioeconomic status, sense of belonging, and availability and quality of mentoring. In addition to these codes, the team paid attention to environmental contexts, such as institutional characteristics. These included, for example, minority-serving institutions, predominantly white institutions, research-intensive universities, and schools with highly selective admissions processes.
10. The report is available from the principal investigator on request: mia_ong@terc.edu.
11. 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 with a caveat that for Asian/Asian American, African/African American, and Latina populations especially, citizenship status could critically affect their experiences in STEM.
12. The perception that Asian American women are doing "fine" in STEM is aided by their visibility on campuses and in industry comprised of large numbers of foreign and international students and employees. Further, there is often conflation of subgroups that have strong representation in STEM (e.g., Chinese, Korean) with those that do not (e.g., Filipino, Vietnamese, Native Hawaiian) (Ong, 2005).

13. Solórzano (1994) specifically refers to this population as Chicanas, so our use of the term reflects the author's choice. For further explanation, we refer the reader to the section "On Terminology," p. 180.
14. Faculty desegregation was required as an essential element of school desegregation by the Supreme Court in its unanimous decision in *Green v. County School Board of New Kent County* (1968).
15. We are referring to studies similar to those of Solórzano (1994, 1995) and Leggon and Pearson (1997) discussed on pp. 190–191.

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