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THE ROAD TO THE STEM PROFESSORIATE FOR UNDERREPRESENTED MINORITIES

A Review of the Literature

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SUBMITTED TO:

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CHAPTER I: INTRODUCTION

Underrepresentation of African Americans [(as well as Latinos and Native Americans)] in doctoral programs and in the professoriate has resulted in a loss of talent to society, the loss of potential research, and the loss of important role models for the next generation of Black students who aspire to educational and professional careers (Solorzano, 1995, p. 15).

More than a quarter century ago, the National Board of Graduate Education convened a special advisory group to examine the status of underrepresented minorities (URMs)[1] in graduate education. The advisory group characterized their underrepresentation in graduate school and among doctoral degree recipients as "striking" (Nettles & Millet, 2006, p. 12). The group declared that "increased minority participation in graduate education is an important national goal to be realized for the social, economic, intellectual, and cultural well-being of all persons" (Nettles & Millet, 2006, p. 15). It also noted that greater graduate education completion among these individuals will yield a "collective benefit" to society.

"Governments throughout the world recognize that a high-skill science and engineering workforce is essential for economic strength. Countries beyond the United States have been taking action to increase the capacity of their higher education systems, attract foreign students and workers, and raise the attractiveness to their own citizenry of staying home or returning from abroad to serve growing national economies and research enterprises" (National Science Board, 2003, p. 1).

More generally, there is reason to be concerned about the low participation rates of URMs in science, technology, engineering, and mathematics (STEM).[2] In recent years the overall production of STEM doctoral degrees in the U.S. has fallen. From 1998 through 2005, the number of U.S. citizens or permanent residents earning these degrees in STEM fields declined just over 13 percent[3], while the number of URMs completing doctoral programs in these disciplines increased only 15 percent[4] (National Science Foundation [NSF], 2008b). These trends have profound implications for the American scientific and engineering workforce, and particularly strong implications for the American STEM professoriate: according to available data, among all individuals earning STEM PhDs in 2003, fewer than 17 percent indicated that they planned academic employment (NSF, 2008b).

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[1] Ordinarily, we would try to avoid using "minority" when referring to these individuals because some can perceive it as suggesting that one group is "less than" another "greater" group, albeit unintentionally. However, in this literature review we use "underrepresented minorities" as more concise terminology when referring to individuals from racial/ethnic groups that are underrepresented in STEM graduate programs and fields; specifically, those who identify as African American/Black, American Indian/Alaskan Native, or Hispanic. Some of the related STEM literature we reviewed also uses this terminology.

[2] When referring to "STEM" fields, this review typically excludes the agricultural sciences, psychology, and the social sciences.

[3] The number of U.S. citizens and permanent residents completing STEM doctoral programs decreased from 11,577 to 10,036.

[4] The number of URMs completing STEM doctoral programs increased from 719 to 830.

Moreover, projected demographic changes raise other concerns about sustaining the STEM workforce. Population declines among White, non-Hispanic males—who represented almost 70 percent of the STEM workforce in 1997—may in the coming years create a population gap in the U.S. workforce (George, Neale, Van Horne, & Malcom, 2001). This gap has significant implications for the future of STEM professionals in all areas.

Although URMs are "an untapped reservoir of talent that could be developed to fill technical jobs," they frequently confront obstacles to their entry and continuation in the STEM education and workforce pathways (George et al., 2001, p. 4; NSF, 2005). These obstacles, which can reinforce each other, often include limited access to rigorous, high quality, and relevant math and science curricula. The high cost of a solid education in STEM and general issues of educational affordability are also significant obstacles for URMs (NSF, 2005). A lack of culturally appropriate (or non-existent) student support systems exacerbates these challenges that are typically present early in the academic pipeline, ultimately leading to student frustration and attrition.

The Alliances for Graduate Education and the Professoriate Program

Partially as a response to these phenomena, the NSF's Alliances for Graduate Education and the Professoriate (AGEP) program is specifically designed to address these obstacles and increase the number of URMs completing STEM doctoral degrees and entering the professoriate. Preliminary evidence suggests that universities participating in AGEP are reversing the aforementioned downward trends; colleges and universities funded under the initiative are reporting "rising doctoral program enrollments, high levels of retention, steady progress toward degree attainment, increases in PhD production, and successful transitioning of PhD graduates into the workplace (including the professoriate)…and more" (NSF, 2006).

Through an NSF grant, the American Institutes for Research (AIR) is conducting a comprehensive evaluation of the AGEP program. The evaluation seeks to determine the value AGEP adds to the recruitment, retention, and graduation of URMs in STEM disciplines and whether the program helps increase participants' interest in STEM professoriate careers. The purpose of this literature review is to inform AIR's national evaluation of AGEP.

This review focuses on participation of URMs in graduate-level education and the professoriate. Shirley Vining Brown noted that as of the late 1990s research on URMs in science and engineering tended to focus on any of four areas: general status of these individuals in science and engineering education and careers, attrition from science and engineering programs, discrimination in science, and the status of female URMs in the science workforce. Correspondingly, several salient themes emerged from our review:

- Access to rigorous and high-quality mathematics and science instruction in elementary and secondary education affects doctoral and post-doctoral participation in STEM.
- Academic and social integration into the STEM disciplines is critical at the undergraduate and doctoral levels.
- Student support systems, in particular mentorship, are integral to retaining URMs in STEM education and careers such as the professoriate.

- Socialization into the rewards of a STEM career, especially in academe, is important.
- A number of factors unique to URMs, such as cultural marginalization, affect the URM students' interest in STEM careers, whether in the STEM professoriate or larger workforce.

For URMs in STEM disciplines, "obstacles [to persistence] can be encountered during the pre-college, undergraduate, graduate, and postgraduate years" (NSF, 2005).

The review follows a "pathways" approach that examines how URMs enter and advance through STEM careers. These pathways include four components. First, "attraction" begins when children and youth are drawn to STEM-related subjects during their elementary and secondary education experiences. "Retention" pertains to why they choose to continue learning these subjects through the undergraduate level and "persistence" focuses on what enables them to pursue graduate education in related disciplines. Finally, "attachment" considers the supports to their entrance and perseverance in the STEM workforce (Committee on Equal Opportunities in Science and Engineering [CEOSE], 2004).

Our methodological approach to the literature review is summarized in Appendix A at the end of this document. The review itself is organized into six chapters. In Chapter II, the review provides recent data and trends on URM participation in undergraduate and graduate STEM programs and the workforce. It also discusses the consequences and implications of failing to address issues of inadequate diversity in the STEM disciplines, especially given the United States' shifting demographics and the global economy of today. Next, Chapter III describes participation in STEM pre-college, undergraduate, graduate, and postdoctoral programs among URMs, focusing specifically on the barriers and challenges related to student enrollment, persistence, and degree completion. Chapter IV focuses on the career paths of URMs and explores the factors affecting their participation and retention in the STEM professoriate. Finally, Chapter V summarizes themes and findings and Chapter VI provides the associated implications for the evaluation of AGEP.

CHAPTER II: TRENDS AND THE CURRENT CONTEXT

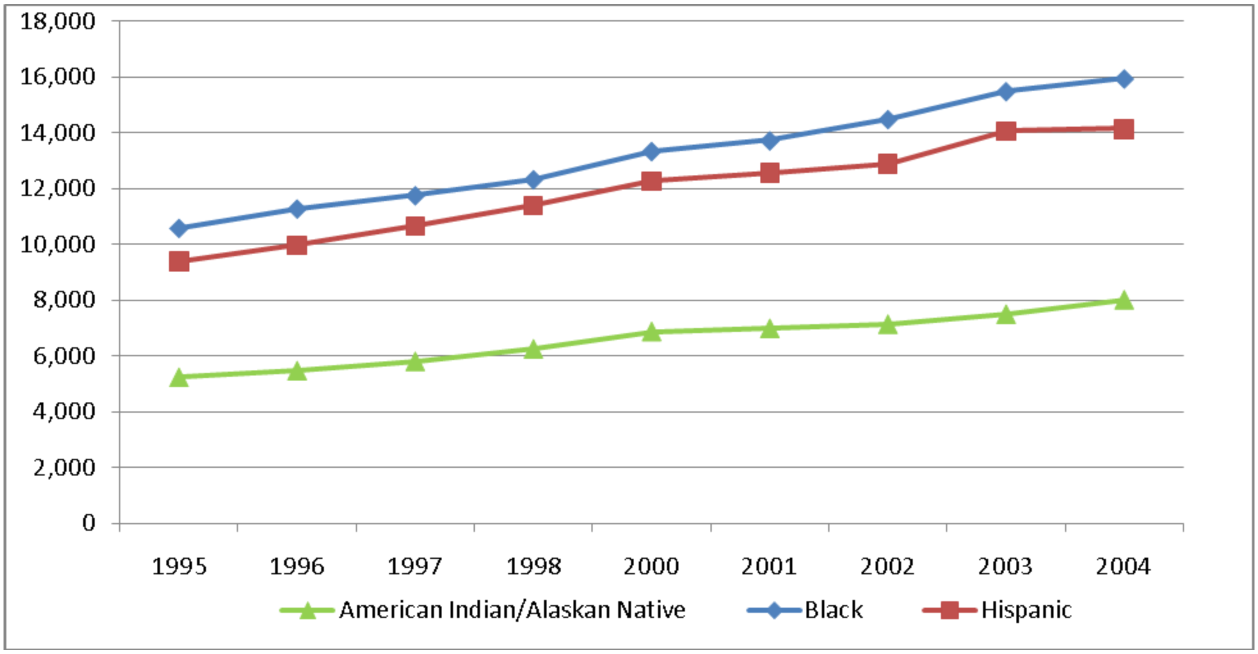
From a historical perspective, as the NSF has noted in its reports individuals in STEM fields have been predominantly (almost 70 percent) White, non-Hispanic males (Congressional Commission on the Advancement of Women and Minorities in Science, Engineering and Technology Development [CCAWMSETD], 2000). This trend persists, even though URMs are becoming an increasingly larger share of the U.S. population. Noting forthcoming changes in the demographic breakdown of the United States, the U.S. Census Bureau projects that the number of White, Non-Hispanic 18- to 24-year-olds will decrease by 10.5% between 2010 and 2025; however, because of higher birthrates and immigration, the Hispanic population will increase by 59.4% during this period (U.S. Census Bureau, Population Division, 2008). The Asian population is also projected to increase by 39.0%.[5] These demographic changes raise challenges from a labor supply perspective: without more sustained training for URMs in STEM fields, the country will experience a large gap in the STEM workforce (George et al., 2001).

UNDERGRADUATE EDUCATION COMPLETION

Increasing enrollments in STEM undergraduate and graduate programs is an important step in trying to fill the workforce gap. Between 1995 and 2004, the number of students completing bachelor's degrees in science and engineering programs[6] increased by approximately 30,000, to just over 200,000. Underrepresented minorities accounted for approximately 38,000 of the 2004 total (see Figure 1 for a breakdown by race/ethnicity). During this period, the percentage of undergraduate URMs obtaining science and engineering degrees increased more than 51 percent compared to an increase of less than 13 percent among non-URMs. Yet, as a share of all students receiving STEM degrees, the percentage of URMs increased only 4.1 percentage points (from 14.9% to 19.0%). Within this context, minority serving institutions (MSIs) have played a significant role for URM students who pursue STEM degrees. For instance, historically black college and universities "have served as the conduit for the education of African American students in science and engineering for over one hundred years" and have had the greatest impact at the undergraduate level (Trent & Hill, 1994, p. 78).

[5] Current U.S. Census Bureau estimates project that the number of Black 18- to 24-year-olds will decrease slightly by 3.4%, whereas American Indians/Alaskan Natives will increase slightly by 3.3% between 2010 and 2025.
[6] Data exclude the numbers of students completing degrees in agricultural science, psychology, and the social sciences.

Figure 1: Underrepresented Minority Undergraduate Science, Technology, Engineering, and Mathematics Bachelor Degrees (1995-2004)



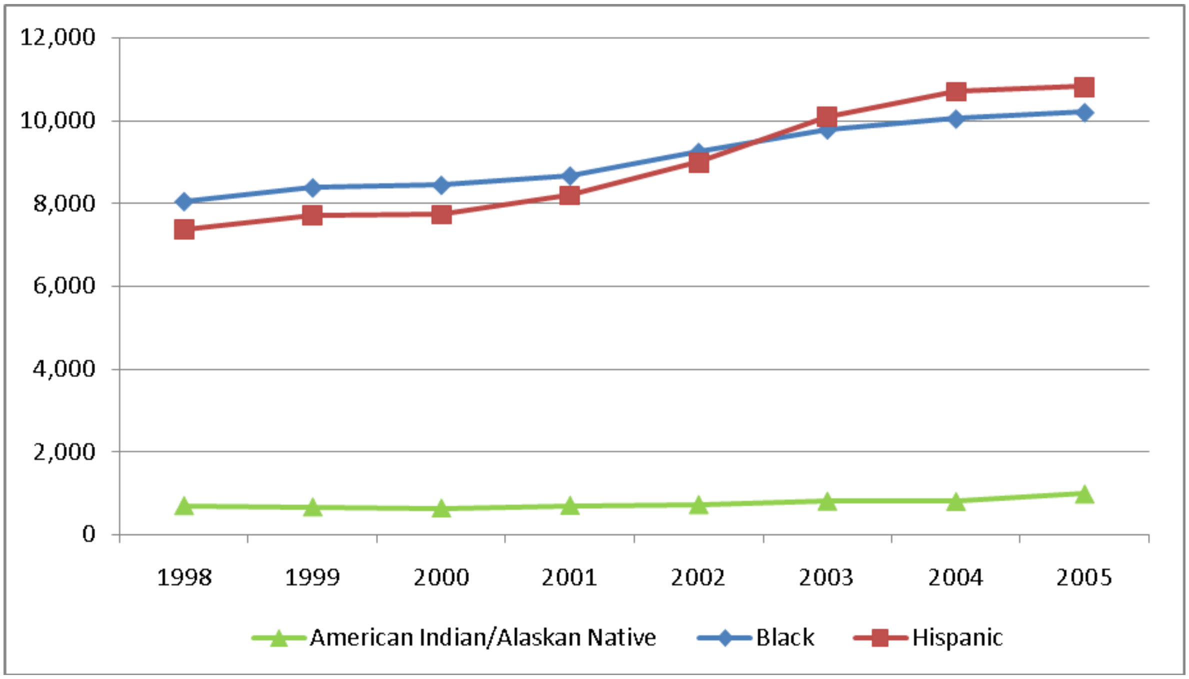
Notes: Data are for U.S. citizens and permanent residents. Data include undergraduate degree completion in the biological sciences; computer sciences; earth, atmospheric, and ocean sciences; engineering; mathematical sciences; and physical sciences.
Source: National Science Foundation, Division of Science Resources Statistics, 2007.

Graduate Education Enrollment

Similar to the trend in undergraduate science and engineering enrollment, between 1998 and 2005 the numbers of URMs enrolling in graduate science and engineering programs increased, both in absolute numbers and as a percentage of the total enrollment in these fields. During this period, the number of White and Asian students enrolling in graduate science and engineering education increased 5.4%, compared to an increase of 36.6% among URMs. Still, in absolute terms, 154,767 White or Asian students enrolled in STEM graduate programs in 2005, compared to only 22,008 URMs. Figure 2 presents these trends. Given that URMs made up 26.7% of the undergraduate population at this time (more than 3.5 million students), these numbers raise concerns.[7] Moreover, although more than 38,000 URMs completed science and engineering bachelor's degrees in 2004, the number of URMs enrolled in graduate science and engineering was only approximately 22,000.

[7] To calculate this percentage, the total number of students enrolled in undergraduate institutions excludes students identified as "other or unknown race/ethnicity," which accounted for 5.9% of the total enrollment, as well as temporary residents (accounting for 2.1% of the total).

Figure 2: Underrepresented Minority Science, Technology, Engineering, and Mathematics Graduate Education Enrollment (1998-2005)



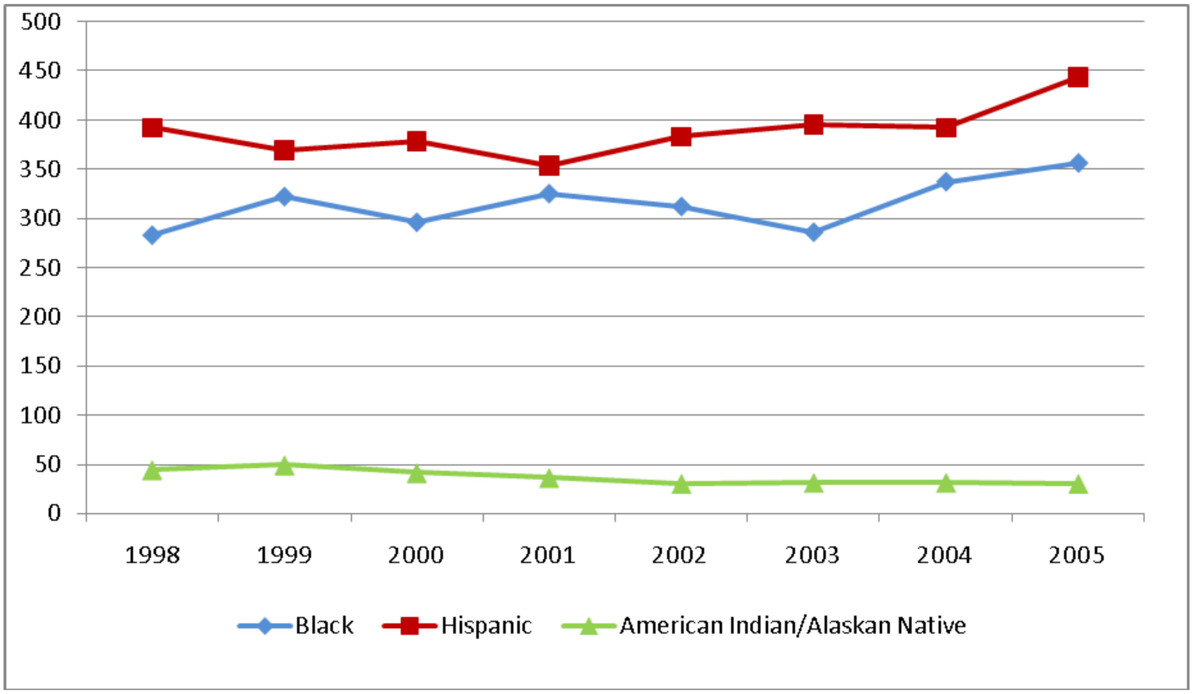
Notes: Data are for U.S. citizens and permanent residents. Data include graduate enrollment in the biological sciences; computer sciences; earth, atmospheric, and ocean sciences; engineering; mathematics and statistics; and physical sciences.
Source: National Science Foundation, Division of Science Resources Statistics, 2008c.

Doctoral Completion

Between 1998 and 2005, the number of URMs receiving science and engineering doctoral degrees tended to increase slightly (see Figure 3). During this period, the number of White and Asian students receiving science and engineering doctoral degrees increased 7.4%,[8] compared to 15.4% among URMs. This growth is minor in absolute terms, though: only 830 URMs received science and engineering doctoral degrees in 2005, compared to 13,906 White or Asian students.

[8] This percentage change was positive among students identified as White (14.1%), but negative among students identified as Asian (-25.5%).

Figure 3: Science, Technology, Engineering, and Mathematics Doctoral Degrees Awarded to Underrepresented U.S. Citizens and Permanent Residents (1998-2005)



Notes: Data are for U.S. citizens and permanent residents. Data include doctoral degrees awarded in the biological sciences; computer sciences; earth, atmospheric, and ocean sciences; engineering; mathematics and statistics; and physical sciences.
Source: National Science Foundation, Division of Science Resources Statistics, 2008b.

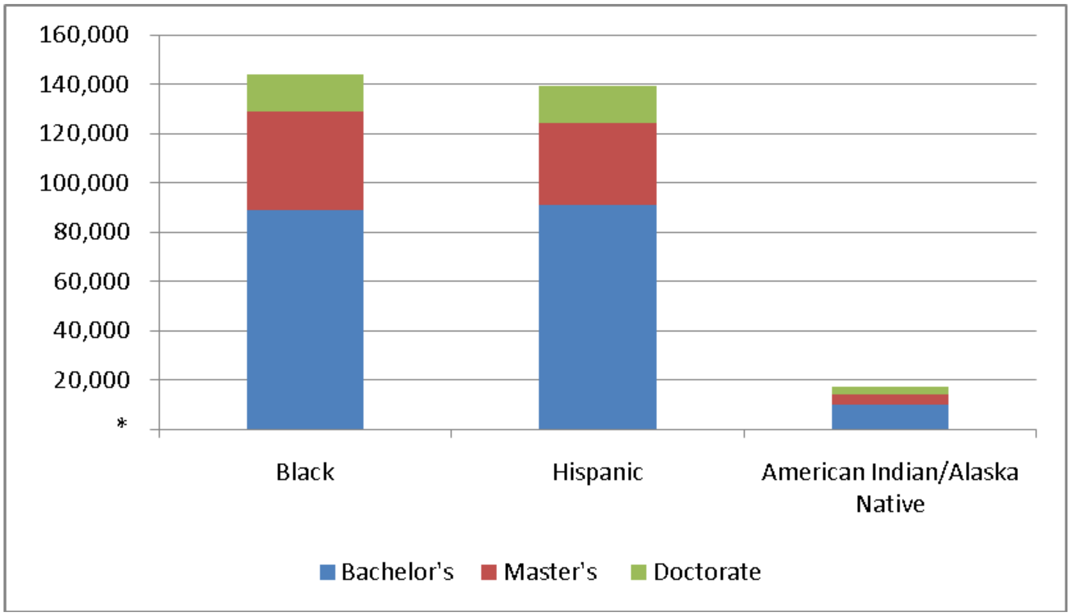
The glacial pace of change in the proportion of doctoral degrees earned by URMs is a long-standing trend. For instance, one earlier study used data from the National Research Council's Doctorate Records Project to examine doctorate production among African Americans in the life and physical sciences and engineering between 1980 and 1990 (Solorzano, 1995). Although the size of the African-American student cohorts grew by almost 40 percent during this period, doctoral program completion by these students decreased by 6 percent during the first half of the decade and then 16 percent during the latter half.

The Workforce and the Professoriate

Since the early 1990s, the participation of African Americans, Hispanics, and Native Americans in the STEM workforce has only marginally increased, and URMs continue to represent a small percentage of scientists and engineers nationally (CEOSE, 2004). In 2006, American companies employed more than 18.9 million people with science and engineering degrees. Approximately 5 million of these people worked as scientists and engineers, while 5.25 million worked in science and engineering-related occupations (e.g., health-related occupation)and the remainder worked in non-science and non-engineering occupations such as sales and marketing (NSF, 2008a). Of the number employed as scientists and engineers, less than 9 percent were Black, Hispanic, or American Indian/Alaska Native. This is a stark contrast to the racial/ethnic composition of the 2006 U.S. population, when 25.1% of Americans 25 years and older were Black/African

American, Hispanic/Latino, or identified as "other"[9] racial/ethnic groups. Figure 4 displays the number of URMs employed as scientists and engineers, by degree level. The numbers employed with only a bachelor's degree suggest a potentially untapped resource for STEM doctoral programs and the professoriate.

Figure 4: Underrepresented Minorities Employed as Scientists and Engineers, by Highest Degree Level (2006)



Note: Data exclude agricultural science, psychology, and social science occupations, as well as science and engineering-related occupations (e.g., science and engineering precollege teacher) and non-science, non-engineering occupations (e.g., sales and marketing).
Source: National Science Foundation, Division of Science Resources Statistics, 2008a.

Noting this disparity, some researchers specifically examine the pipeline of individuals "of color" from undergraduate science and engineering education to the professoriate. For instance, 1990 data show that African Americans, Hispanics, and Native Americans were significantly underrepresented in science and engineering fields, including tenured faculty positions (Turner, Viernes, & Myers, 2000). In fact, in recent years URMs have accounted for only 7.9% of all science and engineering doctorate-held academic positions in universities and four-year colleges (NSF, 2008b).[10] Table 1 presents the percentage of doctorate-holding scientists and engineers employed as postsecondary faculty in STEM fields, by race and ethnicity. As the table shows, as of 2006 a significant majority of doctorate-holding scientists and engineers employed as STEM

[9] "Other" includes American Indians/Alaska Natives, Native Hawaiians/Other Pacific Islanders, and individuals identified as multi-racial.
[10] This proportion increases slightly (to 12.8%) when looking at teaching positions specifically. It decreases, though, for research faculty positions (7.5%) and adjunct faculty positions (6.3%).

postsecondary faculty were White or Asian.[11] For example, in the case of physical scientists, a large majority (93.6%) are identified as Asian or White.

Table 1: Scientists and Engineers with Doctorate Degrees Employed as Postsecondary Faculty in Science, Technology, Engineering, and Mathematics Fields, by Race/Ethnicity (2006)

	Biological/Life Scientist	Computer and Information Scientist	Mathematical Scientist	Physical Scientist	Engineering
American Indian/ Alaskan Native	*	*	*	*	*
Asian	8.8%	33.3%	13.6%	9.7%	19.0%
Black	2.9%	*	4.5%	3.2%	4.8%
Hispanic	2.9%	*	4.5%	3.2%	4.8%
White	82.4%	66.7%	77.3%	83.9%	71.4%

Note: Percentages may not equal 100 due to rounding and suppression—actual numbers are rounded to the nearest 1,000 and values less than 500 are unavailable.(*)For example, fewer than 500 computer and information scientists identified as Black or Hispanic are employed as postsecondary faculty. Consequently, the reported percentages exclude information about this population. Similarly, the number of American Indian/Alaskan Natives employed as postsecondary faculty is less than 500 in all fields.
Source: National Science Foundation, Division of Science Resources Statistics, 2008a.

The situation of females from underrepresented backgrounds warrants special concern. Underrepresented females are nearly invisible on science and engineering faculty, with studies finding they are less likely to attain tenure than White women or males of any racial group (Nelson, 2007). In the physical sciences and engineering in 2002, the top 50 science and engineering departments[12] had only 20 females who were Black and 33 who were Hispanic. Of these, only one Black female and 10 Hispanic females were full professors (Nelson, 2007).

The continuing lack of full and diverse participation of all citizens in the science, technology, engineering, and mathematics (STEM) workforce threatens the economic strength, national security, and well-being of U.S. citizens. The under-representation of certain groups [(e.g., African Americans, Latinos, and Native Americans)] also raises serious issues of social justice and lack of opportunity in a society that professes to be egalitarian and democratic. As groups under-represented in the STEM workforce become an increasingly larger part of the U.S. population, the vitality of the STEM workforce may further decline unless action is taken to broaden participation of all parts of our society (NSF, 2005, p. 3).

[11] The approximate total number of doctorate-holding scientists and engineers employed as postsecondary faculty is highest in the case of biological/life scientists (34,000) followed by physical scientists (31,000). The figure is lowest (9,000) for computer and information scientists. The number of engineers (21,000) and mathematical scientists (22,000) employed as postsecondary teachers falls in the middle range.
[12] The author ranked programs according to the size of their research expenditure using the most current data from the National Science Foundation.

SUMMARY

Trends in the participation and completion of STEM doctoral degrees among URMs should concern U.S. policymakers, STEM academics and other professionals, and the broader public. Diversity arguably "makes the university educational and learning experience richer and more valuable for all students" (Burke, 2007, p. 7). Moreover, minorities (like women) "represent an untapped resource": industries needing skilled STEM employees are unable to benefit from their abilities (Burke, 2007, p. 7). This is a "real loss" for "faculty, their graduate programs, and for other researchers…all have lost trained talent, cultural energy, and creativity" (Ibarra, 2000, p. 148).

Scientific knowledge, as well as innovations in engineering and technology, have driven economic growth since the Industrial Revolution and significantly influence quality of life (National Academy of Sciences [NAS], National Academy of Engineering, and Institute of Medicine, 2007). Technological investment, of which the STEM workforce is a core component, is critical to enhancing quality of life (NAS et al., 2007). Enhancing the STEM workforce's diversity is important to U.S. productivity and economic strength and may help enhance the STEM labor supply to industries that, in some cases, are turning to guest workers or exporting jobs to other countries (George et al., 2001; NSF, 2005). For example, geosciences employers are turning to foreign citizens for the skills necessary to meet the industry's labor market needs (Huntoon, Peach, & Hopkins, 2005). Some even say the science workforce is "in danger" (Preston, 2004, para. 1). Shirley Ann Jackson (2003), President of Rensselaer Polytechnic Institute, has emphasized the urgency of a "quiet crisis" emerging in the U.S.:

> *A crisis that could jeopardize the nation's pre-eminence and well-being. The crisis has been mounting gradually, but inexorably, over several decades. If permitted to continue unmitigated, it could reverse the global leadership Americans currently enjoy* (p. 1).

But despite this "crisis," URMs may perceive a dearth of attractive science and engineering career opportunities (CEOSE, 2004). In some instances, this perception may be rooted in the early educational experiences of URMs. If as a population URMs do not have access to, or do not enroll in, advanced mathematics and science courses during the middle and high school years, it is improbable that they will consider STEM careers. The lack of early role models and exposure to STEM may limit their sense of a viable future in these fields. Inadequate mentorship for URMs is a recurring issue at the undergraduate and graduate levels, and may further constrain their understanding of potential STEM education and employment opportunities. Moreover, the barriers and challenges (e.g., cultural marginalization, stereotype threat) URMs experience along their journey to the professoriate or other STEM occupations may leave a negative impression about these career choices.

The next chapter of the review explores extant literature on the obstacles in the doctoral and professoriate pathways of individuals underrepresented in STEM fields. Understanding these challenges within the context of a pathways framework is critically important, as URMs encounter obstacles during elementary-secondary, undergraduate, graduate, and postgraduate education as well as when they enter the professoriate. Obstacles faced throughout a pathway can lead to attrition in early stages of one's education and professional training, resulting in lower levels of URM representation in the STEM professoriate and a parallel decreased share of the non-academic labor market supply. Obstacles in the pathways thus exacerbate this “quiet crisis.”

CHAPTER III: SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS PARTICIPATION AMONG UNDERREPRESENTED MINORITIES

Beginning with the Science and Engineering Equal Opportunities Act of 1980, NSF has funded a number of programs designed to strengthen STEM-related policies and programs and, in particular, to increase the participation of underrepresented individuals including minorities, women, and students with disabilities. NSF increased its financial investments in programs focused on URMs, and reformulated its merit-review criteria[13] to include a focus on integrating into NSF programs, projects, and activities. The Department of Energy, the National Institutes of Health (NIH) and other Federal agencies have also initiated programs to increase the proportion of URMs in the STEM community (Baker, 1998). These efforts increased educational grant applications by members of underrepresented groups, and beginning in the early 1990s minority participation in undergraduate and graduate education began to increase (CEOSE, 2004).

Research findings suggest that universities have also increased efforts to diversify their student population and admit URMs (Attiyeh & Attiyeh, 1997).[14] However, despite the efforts of NSF and the universities, URMs are not enrolling, persisting, and obtaining advanced degrees at the same rate as other students. Several challenges and barriers continue to affect STEM program enrollment and persistence among URMs. These individuals experience challenges at the pre-college, undergraduate, graduate, and postgraduate educational levels (NSF, 2005) and are discussed in greater detail below.

ATTRACTION TO SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS

Access

Challenges to enhancing URMs' pathways to STEM careers begin early in students' academic experiences. Although educational access for URMs has progressed, disparities persist and improvements have been uneven and largely insufficient. The elementary-secondary education system tends to underserve students from impoverished underrepresented groups, even though members of these groups are likely to have the greatest educational needs (NSF, 2005). For example, these students are more likely to have teachers without degrees in the subjects they teach and are more likely to attend public schools with inferior physical facilities and laboratories; they often lack access to high-intensity math and science curricula, and computers and other modern technologies (CCAWMSETD, 2000; McBay, 2003; Wilson, 2000).

[13] Merit review is a component of NSF's decision-making process for funding research and education projects.
[14] This research study (1990-1991) analyzed applications and admissions data from 48 leading institutions of higher education (IHE) for five disciplines (biochemistry, economics, English, mathematics, and mechanical engineering). The study sample consisted of 29,260 records in 1990 and 32,137 records in 1991. Each record corresponded to an application for admission to one of the participating institutions in one of the five fields (biochemistry, economics, English, mathematics, and mechanical engineering). Each record also included data on admissions status, aptitude and achievement measures, and demographic characteristics.

Additionally, among middle and high school students, URMs are less likely to enroll in advanced mathematics and science courses, limiting their likelihood of success in a related career (Payton, 2004). The most recent results of the National Center for Education Statistics (NCES) National Assessment of Educational Progress (NAEP) Transcript Study[15] demonstrate significant differences in the mathematics and science courses that high school students of differing race/ethnicity complete, on average. Among Asian/Pacific Islander high school graduates, 62 percent completed advanced mathematics courses compared to 46 percent, 29 percent, and 28 percent of White, Black, and Hispanic graduates, respectively. The trend is similar for high-level science or physics courses: 62 percent of Asian/Pacific Islander graduates completed these courses, compared to 46 percent, 34 percent, and 32 percent of White, Black, and Hispanic graduates, respectively (NCES, 2007).

Academic, social, and cultural barriers

Perhaps because of weak training in STEM at the elementary and secondary school levels, URMs typically exhibit little confidence in their mathematics and science abilities and often lack assurance when applying their reasoning skills to solve problems. Such low expectations in one's ability correspond to achievement discrepancies (Clewell, Anderson, & Thorpe, 1992). These early educational experiences appear to influence later achievement, suggesting that beyond the issues associated with access, student performance and student aspirations can also be significant obstacles to increasing the enrollment and persistence of URMs in undergraduate, master's, and doctoral and post-doctoral STEM programs. Research indicates that "how bright the student is, the level of background preparation, and the intensity of personal ambition and striving will all influence academic performance outcomes" (Allen & Haniff, 1991, p. 108). For example, the results of a study using a nationally representative sample of 1992-1993 bachelor's degree recipients suggest a relationship between undergraduate grade point average (GPA) and a student's decision to apply and enroll in graduate or professional school[16] (Millet, 2003). Furthermore, studies examining the precollege experiences of Blacks[17] demonstrate that even those who have high educational aspirations and abilities will sometimes opt out of a college education for the military, immediate employment, or vocational education, perhaps because of a lack of precollege socialization and orientation toward higher education (Thomas, 1987).

Females from underrepresented groups may be doubly affected by their early educational math and science experiences. The literature suggests that girls' poor attitudes toward STEM are closely tied to factors that make the subject unattractive (Burke, 2007). For example, science curricula are irrelevant to many girls because of a lack of female role models and the scant attention paid in class to women's contributions to the field. Similarly, the pedagogy of science classes appears to favor male students. Females may also feel cultural and social pressures early

[15] The study collected transcripts from a nationally representative sample of 26,000 U.S. high school graduates in 2005, representing approximately 2.7 million U.S. high school graduates from public and private schools across the country.

[16] The study's sample came from the Baccalaureate and Beyond (B&B) Longitudinal Study of 1992-1993 college graduates. This is a subsample of the National Postsecondary Student Aid Study (NPSAS), a nationally representative sample of all postsecondary students. The conceptual model for the study is intended to show the relationship of students' academic and personal backgrounds (including undergraduate debt and immediate opportunity costs to attend graduate school) to their transition to graduate and first professional school immediately after completing college. The researchers performed both descriptive and relational data analyses.

[17] See Allen, 1986; Portes & Wilson, 1976, as cited in Thomas, 1987.

in their academic careers to fulfill their teachers' expectations and to conform to more traditional gender roles (Blickenstaff, 2005; Clewell et al., 1992). These phenomena are especially problematic for African-American females, as studies have found that the number of high school math and science courses African-American females complete affects their decisions about undergraduate majors (Clewell & Ginorio, 1996).

Many individuals who are underrepresented are either "forced out of the pipeline" due to lack of science and math preparation in high school or require "remedial assistance to prepare them for the gatekeeper courses required of science and engineering majors…they become discouraged and do not see science and engineering majors or careers as realistic choices" (McBay, 2003, para. 12-13).

Underrepresented males may also experience cultural and social pressures that are obstacles to success in STEM disciplines. The public continues typically to view scientists, mathematicians, and engineers as White males. This image is less accepting of URMs (regardless of gender) and may affect both male and female students' decisions to remain in or pursue advanced education and careers in STEM fields (CCAWMSETD, 2000; Payton, 2004). This perception may also affect teachers' attitudes toward students and the expectations the teachers hold for individuals of a particular race/ethnicity or gender (Blickenstaff, 2005).

Given these factors, upon entering college, many URMs are "forced out of the STEM pipeline" because of a lack of science and math preparation in high school. Alternatively, they often require "remedial assistance to prepare them for the gatekeeper courses required of science and engineering majors" (McBay, 2003, para. 12). When confronted with these challenges, URM students frequently forego opportunities to enroll, major, and (or) persist in academically rigorous disciplines such as STEM; rather, they "become discouraged and do not see science and engineering majors or careers as realistic choices" (McBay, 2003, para. 13).

RETENTION: UNDERGRADUATE EDUCATIONAL EXPERIENCES

In addition to inadequate preparation in elementary and secondary school for the pursuit of STEM at higher levels, the persistence of URMs in STEM at the undergraduate level is further affected by a number of other factors. These factors include the costs associated with attending post-secondary school and the admissions policies and practices of undergraduate institutions. The factors also include the URM's overall educational experience and the existence of effective systems that support URM's academic and social integration into STEM departments.

Educational affordability

The high cost of financing postsecondary education in STEM fields is a significant obstacle for all students, but particularly for URMs. Native Americans, African Americans, and Hispanics are disproportionately from low-income backgrounds and they generally require more financial aid to support their academic endeavors than do Whites.

The high costs associated with obtaining a STEM degree magnifies this problem. A systemic study of tuition costs found that 30 percent of the nation's public research universities employ "differential tuition" practices, charging undergraduates a premium to major in science-related programs such as engineering (Benderly, 2008). Moreover, recently IHEs have tended to move away from need-based financial aid toward merit-based scholarships as they compete for students with the highest test scores and GPAs (Atwell, 2004; Matthews, 1990). Consequently, many students from low-income backgrounds are left with significant gaps between their financial aid packages and tuition costs (Melendez, 2004). Others have further argued that "students with limited grant and fellowship aid or with extensive work commitments cannot realistically expect to major in chemistry, biology, and other fields that require extensive laboratory work and out-of-class assignments" (Thomas, 1987, p. 277).

These high costs are especially worrisome considering the relatively lengthy time-to-degree patterns in STEM fields of study, particularly for URMs. Research findings suggest that Hispanics and Blacks complete undergraduate STEM degrees at a slower rate than Whites and Asians (Fenske, Porter, & DuBrock, 2000), increasing the years in which financial aid is needed.

Admissions policies and practices

Given the aforementioned challenges related to K-12 pathways to STEM education, URMs often "approach college with serious academic handicaps that severely limit their access to competitive universities and rigorous academic programs" (Wilson, 2000, p. 196). These challenges are most pronounced when approaching STEM programs, which have rigid admissions standards. Undergraduate programs requiring or preferring high scores on the College Board's SAT Reasoning Test may also limit educational access among students from underrepresented groups (Wilson, 2000).

The recent trend toward anti-affirmative action or "race-neutral" admission policies may further hinder the participation of URMs in STEM, as the policies have led to declining enrollments of URMs overall. Public universities in states such as California, Florida, Georgia, Texas and Washington have faced legislation or court orders essentially banning them from applying race conscious admissions practices (Cross, 2000). The University of California, as one example, appears to have been hard hit by the ban. Its race-neutral policy for undergraduate admissions (a result of state referendum Proposition 209) went into effect in 1998 and "the next year there was a calamitous drop in the number of undergraduate Black students at the prestigious Berkeley campus. First-year Black enrollments declined 59 percent from 273 in 1997 to 113 in 1998" (Cross, 2000, p. 68).

Although the 2003 U.S. Supreme Court ruling involving the University of Michigan (*Grutter v. Lee Bollinger, et al.*) allows undergraduate admissions offices to use race as one of several factors in their decisions, other court decisions indicate support for a zero-tolerance approach to all race-based practices or initiatives.[18] Growing hostility to affirmative action practices may lead to elimination of other programs that benefit underrepresented individuals and that enhance their participation in campus life. Vulnerable practices include:

- Orientation programs for entering individuals who are underrepresented,

[18] For example, *Adarand Constructors v. Pena*, 515 U.S. 200 (1995); *Richmond v. Crosen*, 488 U.S. (1989); and *Miller v. Johnson*, 515 U.S. 900 (1995), as cited in Cross (2000).

- Tutoring programs for inner city youth,
- Same-race mentoring sessions between alumni and students,
- Grants from private foundations to advance recruitment, mentoring, and training of minority students in disciplines where they are underrepresented (i.e. Gates Millennium Scholarship),
- English language immersion courses for students who speak English as a second language,
- Literary prizes awarded only to students of color to encourage literary efforts by minority students, and
- University support of black student organizations, sororities and fraternities (Cross, 2000).

On the other hand, the effect of affirmative action on student performance has also recently been researched[19] and the findings suggest that the negative stigma attached to affirmative action policies may lead to feelings of "performance burden," directly and indirectly affecting the grade performance of URMs: "directly, it creates a stigmatizing social context within which Black and Latino students find it more difficult to perform. Indirectly, it heightens the subjective performance burden experienced by individual minority students" (Charles, Fischer, Mooney, & Massey, 2009, para. 9).

Despite these findings, the researchers argue that affirmative action is "right in theory" just "wrong in practice." They conclude that their findings tell us "less about the inherent weakness of affirmative action than about the poor fashion in which programs are carried out" (Charles et. al., 2009, para. 17). Indeed, if the stigma associated with affirmative action can be mitigated so that URMs are not burdened by the perceived low opinion of their abilities by faculty and peers, the negative performance effects may diminish (Charles et al., 2009). Moreover, it has been argued that by eliminating affirmative action and related policies, the "danger lies in sending the implicit message that we have won the battle for equity and equal opportunity" (Melendez, 2004, p. 7).

Educational experience and quality

The literature suggests that the overall undergraduate educational experience also affects the doctoral and post-doctoral plans of underrepresented individuals. Unfortunately, as will be discussed below, URMs often experience challenges during these academic years, particularly students who might enter STEM fields of study. Institutional practices in the sciences and engineering frequently assume that "all students are immediately ready for a rigorous and heavy course of study without too much help," and will acclimate to the programs with ease (Wilson, 2000, p. 197). In practice, though, not all students are ready for the course load or prepared to acclimate to the campus culture. Furthermore, URMs may have negative feelings about their academic and social environments if they have not been well socialized and integrated into their discipline of study and campus life.

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[19] Researchers used SAT scores to measure the impact of affirmative action on the grade performance of specific Black and Latino students at 28 colleges and universities.

A teaching culture within STEM that pays inadequate attention to individual students can contribute to these negative feelings. Chickering and Gamson (1987) lay out seven research-based principles of effective undergraduate teaching practices in IHEs:

- Frequent student-faculty contact,
- Reciprocity and cooperation among students,
- Application of active learning techniques,
- Prompt feedback to students,
- Emphasis on time on task,
- Communication of high expectations, and
- Respect for diverse talents and ways of learning.

Although these practices can benefit all students—those from underrepresented groups as well as Whites—research universities typically maintain a more traditional approach to undergraduate education, one that is largely lecture-based and characterized by little faculty–student interaction (Herzig, 2002; Spalter-Roth, Fortenberry, & Lovitts, 2007).

Research also suggests that the freshman year experience in particular is important to a student's decision to persist with a degree program; hence, attrition rates are highest in the first semesters of coursework (Kramer, 2005). For students interested in a STEM career, this pattern may especially be the case. The freshman-year STEM curricula consists of demanding, largely lecture-based classes that essentially "weed out" students who may not have the potential to succeed in the scientific and technical fields (Cooney et al., 1990; Kramer, 2005). Critics of engineering education commonly agree that this weeding process impacts the retention rates of individuals who are disproportionately represented and that the field could benefit from providing introductory courses that are more interdisciplinary. A Boyer Commission (1998) report on Educating Undergraduates in the Research University, *Reinventing Undergraduate Education*, states that:

> *The freshman year needs to perform two vital functions: it must be the bridge between high school and home on the one side and the more open and more independent world of the research university on the other, and it must excite the student by the wealth, diversity, scale and scope of what lies ahead. If it does not perform both [of] these functions successfully, the entire university experience is at risk* (p. 19).

Beyond the freshmen year, evidence also suggests that students majoring in a STEM field reap considerable benefits from engaging in undergraduate research opportunities (UROs). In an NSF-sponsored study, STEM graduates were asked to describe their experiences participating in UROs funded by NSF; specifically, whether or not they participated and the nature of these experiences.[20] The data were analyzed to determine the effect these experiences had on students' career decisions and their decisions to pursue an advanced degree in STEM. The researchers

[20] Approximately 3,400 individuals were included in the STEM graduates survey. All respondents had received a STEM bachelor's degree between 1998 and 2003.

found that participation in UROs did indeed have a positive effect on students' likelihood of attaining a doctorate, perhaps due to the confidence they gained as a result of the experience. Students who participated in UROs were almost four times more likely to pursue a doctorate than their peers who did not engage in sponsored research. Additionally, participation in UROs seemed to especially benefit some URMs. For example, "Blacks and, especially, Hispanics were more likely than Asians or Whites to have shown gains in understanding, confidence, and awareness" (Ailes et al., 2003, p. ES-5). However, the study also found that students who sought out and participated in UROs are also those students who initially expected to obtain an advanced degree, emphasizing again the importance of meaningfully engaging and supporting URMs in STEM early in the academic pathway.

Finally, the type of IHEs that URMs attend as undergraduates may also affect student interest, enrollment, and successful participation in STEM doctoral and post-doctoral education. From 1986 to 2006, the percentage of Black science and engineering doctorate recipients earning their baccalaureate degrees from historically black colleges and universities (HBCUs) increased four percentage points, from 25 to 29 percent (NSF, 2008a). These data could suggest that HBCUs play a positive role in graduating Black students who have pursued an interest in science and engineering fields; that is, HBCUs may arguably provide, an environment that fosters a positive experience for Black students and prepares them for STEM graduate study (Trent & Hill, 1994). However, these data are not conclusive. Other data demonstrate that the proportion of African-American science and engineering bachelor degree recipients who have graduated from non-HBCUs compared to HBCUs and transition into graduate study is almost the same (Trent & Hill, 1994). Likewise, a study[21] examining the status of STEM doctorate production among African Americans in IHEs during the 1980s (i.e. 1980-1990) found that African Americans students often attend undergraduate institutions where research is not the primary mission. This primary educational focus is typical of most HBCUs, but the focus is not limited to such institutions. (Solorzano, 1995).

The type of institution attended may similarly influence trends among Hispanic students. Approximately 45 percent of all Latina/o students attend a Hispanic Serving Institution (HSI), of which there are 230 in the United States (Contreras & Gandara, 2006). Since at least 25 percent of students at HSIs are Latina/o, some researchers assume that these colleges and universities may more successfully facilitate their students' academic and social integration. The assumption is that because of their critical mass of Latino students, the schools offer Latino students a more familiar and supportive environment. However, more than half of the 230 HSIs are two-year colleges. HSIs also tend to be "non-selective institutions with relatively low graduation rates, and only 2 percent actually offer the doctorate, Consequently few Ph.Ds are produced in HSIs" (Contreras & Gandara, 2006, p. 97).

In the end, data continue to demonstrate that there is substantial racial and ethnic variation among institutions of varying levels of selectivity; Black and Hispanic mathematics, science, and engineering student majors are more highly concentrated in the least selective institutions (Mullen & Baker, 2008). These findings have worrisome implications since it has been argued

[21] This study used 1980-1990 data from the National Research Council's Doctorate Records Project and focused primarily on the production and baccalaureate origins of physical science, life science, and engineering doctorates who were African American from. Data were disaggregated by gender, field, and baccalaureate origin.

that "it is well known that graduate school admissions and many merit-based scholarships, fellowships, and assistantships use the quality of the undergraduate institution as an important selection criteria *[sic]*" (Solorzano, 1995, p. 26).

Faculty mentorship

As indicated above, the typical research university emphasizes faculty's research activities and evaluates faculty performance based on their research productivity, ability to generate research-related funding, and scholarly publications. There is less focus on their use of outstanding teaching methods. As such, faculty members tend to invest their time and energy in achieving their research objectives rather than ensuring interactive, collaborative, and inquiry-based undergraduate learning experiences (Ambrose, 2007; Kramer, 2007).

> *The "lack of diversity in the student population, faculty, staff, and curriculum often restrict the nature and quality of minority students' interactions within and out of the classroom, threatening their academic performance and social experiences" (Swail et al., 2003, p. viii).*

This lack of student-faculty interaction may have significant implications, as the absence of a student support system has been linked to higher program attrition rates (Brazziel & Brazziel, 2001; Golde, 2005; Herzig, 2002; Taylor & Antony, 2000). Underrepresented minorities who are inadequately prepared for the demands and work required in higher education can experience a kind of "culture shock." Additionally, the "lack of diversity in the student population, faculty, staff, and curriculum often restrict the nature and quality of minority students' interactions within and out of the classroom, threatening their academic performance and social experiences" (Swail, Redd, & Perna, 2003, p. viii). As part of an exploratory study looking primarily at science and engineering undergraduate students, investigators asked students about their decisions to not pursue doctoral education. Respondents consistently noted that dissatisfaction with the student-advisor relationship was a recurring reason and many described their advisors as unhelpful, indicating that advisors broached the possibility of graduate school with only those students who had exceptionally high grades and test scores (Brazziel & Brazziel, 2001).

Social and academic integration

The literature suggests that the creation of supportive learning communities for students from underrepresented backgrounds leads to students' social and academic integration into campus life. Tinto (1986; 1993) identifies and describes three stages of transition that apply directly to students' decisions to persist in or exit a program of study:

- Foremost, students must separate or disassociate themselves from membership in their past communities.
- Next, students begin to form new bonds in their college environment.
- Finally, students become fully integrated into the community of the college.

In other words, academic success depends on students' level of identification with their program of study, their sharing of a campus' normative attitudes and values, and the extent to which the school community accepts and values them as viable members (Herzig, 2002; Rodriguez, 1993; Taylor & Antony, 2000). Thus, student retention, satisfaction, and stability within IHEs are often related to students' self-perceptions within these social and academic contexts (Bonner & Evans, 2004). However, gaining positive self-esteem, a sense of personal efficacy, and progressing through Tinto's stages of transition, can be particularly difficult for URMs, especially those who lack role models, feel threatened by negative stereotypes, and (or) experience marginalization. Gay (2004) posits three forms of marginalization for URMs:

1. Physical, cultural, and intellectual isolation;
2. Benign neglect; and
3. Problematic popularity.

Physical, cultural, and intellectual isolation. "Physical, cultural, and intellectual isolation" occurs when students are one of a few from an underrepresented group. Being in the minority can result in feelings of isolation both in the classroom and in campus life. The lack of faculty from underrepresented groups—especially in science, mathematics, and engineering programs—exacerbates these issues and affects career guidance and mentoring efforts (Wilson, 2000). Students generally experience few on-campus images of diversity, leaving nontraditional students "feeling as if they were guests on their own campuses. As such they cannot ever totally relax and genuinely join the hosts" (Gay, 2004, p. 269). Indeed, some have argued that the absence of viable role models as mentors and academic advisors is probably the most "formidable obstacle to academic integration for African American [*sic*] collegians," (Bonner & Evans, 2004, p. 11). This absence and the resulting obstacle are likely the case for other URMs.

The classroom experience, where URMs may sense a lack of value and respect for their thoughts and ideas, can intensify this feeling of isolation. This sense of isolation, in turn, may lead to frustration and "silencing." When students sense disrespect or inadequate appreciation of their contributions, they will often hesitate or be reluctant to share their perspectives in the classroom (Gay, 2004; Milner, 2004). Teamwork and team assignments can reduce the isolation that URMs experience in STEM programs, although students who are expected to create their own teams tend to do so with students like themselves—this makes it difficult for students in the minority to participate (Busch-Vishniac & Jarosz, 2007). Hence, STEM faculty should understand teamwork dynamics to effectively reduce feelings of isolation.

Benign neglect. Underrepresented minorities may also experience "benign neglect"; that is, they encounter professors and advisors who provide vague and ambiguous feedback rather than "the kind of critical and constructive instruction that they need to develop their intellectual, research, writing, and teaching skills" (Gay, 2004, p. 277). Specifically, in interacting with students professors and advisors engage in benign neglect when they:

- Provide ambiguous feedback on writing assignments;
- Allow students to select a research topic, but then are unable to provide sufficient guidance on it (e.g., a topic focusing on ethnic and cultural differences); and

- Withhold critical guidance and teaching during the writing process by not insisting on and facilitating scholarly writing (Gay, 2004).

URMs may experience benign neglect more than their peers who are White because professors and other faculty may be disinclined to provide URMs direct and constructive feedback; a discomfort with or inability to engage in a meaningful way with students of different races or ethnicities (Gay, 2004) inhibits constructive communication. Regardless of the rationale for such behavior, this pattern is a disservice to students, as they do not receive opportunities to improve their performance and work quality. The students' ability to effectively meet the rigorous standards necessary for success in a STEM academic or professional community are constrained. Students are also likely to become frustrated and dispirited, increasingly convinced that an alternate degree is more attainable or attractive.

> *"I don't want to trail-blaze in race relations at the university. I want to focus on my research…that's my focus….let me be me, let me shine…let me do my work" (Chubin, 2007, pp. 94-95). – A Packard Scholar*

Problematic popularity. "Problematic popularity" occurs when IHEs call upon URMs to serve as token representatives of diversity, or when IHEs unfairly or inappropriately identify them as experts on the experiences or issues associated with their culture, gender, race or ethnicity, or other characteristic. Such pressures and expectations can lead to anxiety and hinder students' efforts to complete their work successfully (Gay, 2004; Milner, 2004).

Stereotype threat. Underrepresented minorities face another unique burden that goes beyond the social isolation discussed by Gay (2004). These students face the burden of invalidating stereotypes, particularly those stereotypes that mark one as intellectually inferior. This burden may depress or threaten student performance.

"Stereotype threat" or "the existence of a negative stereotype about a group to which one belongs means that in situations where it is potentially applicable, one risks confirming that stereotype, both to oneself and others" (Steele & Aronson, 1998, p. 422). Stanford University conducted a series of experiments with undergraduates to study this phenomenon. The results suggested that making African-American students more aware of negative stereotypes about their intellectual ability as a group negatively affected their test performance relative to their White peers. Likewise, experiments with conditions designed to alleviate stereotype threats improved their relative test performance (Steele & Aronson, 1998).

> *"The problem that I and a lot of colleagues have is that we are called upon to do a lot of diversity issues for the university. To sit on panels every time a black student is invited to the school…to take pictures for publications that show the diversity of the university. While we are doing these things, our counterparts are in the lab doing research and producing publications. It's just the torn feeling that I have ….I have an extra burden not carried by my majority colleagues" (Chubin, p. 94). – A Packard Scholar*

In contrast, programs designed to promote positive educational experiences for URMs have demonstrated some success. For example, the Louis Stokes Alliances for Minority Participation (LSAMP) Program[22] is one such effort that emphasizes the integration of students into the academic institution as well as the notion of "'disciplinary socialization,' which is the process through which students become socialized into science as a profession" (Clewell, Cohen, Tsui, & Deterding, 2006, p. v). As part of an evaluation of this program, interviewed staff members indicated that the program promoted institutional culture, policies, and practices that encouraged the recruitment, retention, and graduation of students who are underrepresented in STEM majors and subsequently, enabled institutions to retain and graduate more STEM students. Additionally, "analyses of survey data revealed that the vast majority of program graduates (close to 80 percent) sought additional education after obtaining a bachelor's degree, and two-thirds of participants later enrolled in graduate school, working towards at master's, doctoral, or professional degree" (Clewell et al., 2006, p. v).

PERSISTENCE: GRADUATE EDUCATIONAL EXPERIENCES

Educational affordability

Research suggests that URMs may be differentially affected by financial aid practices and that the type and amount of financial aid URMs receive affects graduate school persistence. In master's and doctoral programs, African-American graduate students are more likely than their White counterparts to finance their education with loans and are more likely than White graduate students to receive Federal financial aid (Cross, 2002). Interviews with 77 Latino and Latina graduate students in 1994 and 1995 revealed that 80 percent of respondents could not have attended graduate school without financial support from family, fellowships, grants, or assistantships (Ibarra, 2000). Moreover, a longitudinal study (1989-1992) examining the persistence patterns and student financial aid received by African Americans, Hispanics, Native Americans, and women in science, engineering, and mathematics, found that departure rates within these fields were highest for underrepresented students and students who required financial aid (Fenske et al., 2000).[23]

For many of today's scientists, time in graduate school and post-doctoral research can span up to 10 years, a quarter of a 40-year career (Barnhill & Stanzione, 2004). Persistence is thus affected because as time-to-degree increases, debt amounts grow and students are more likely to exit their program early, especially those who are differentially affected by financial burdens (Barnhill & Stanzione, 2004; Fenske et al., 2000). URMs with significant amounts of academic debt may therefore experience greater pressure to leave their graduate programs.

Additionally, URMs frequently need to subsidize the costs associated with attending IHEs by taking on jobs outside of the university. For students who work part time to offset tuition expenses, the number of hours worked appears to negatively influence the students' rate of

[22] The National Science Foundation established the LSAMP program in 1991 to increase the quality and quantity of URMs who successfully complete STEM baccalaureate degree programs and subsequently matriculate into STEM graduate study.
[23] Data were obtained from the Financial Aid and Academic Progress (FAAP) data warehouse. The study focused on four cohorts of undergraduates with at least five years of enrollment data and analyses focused on the distribution and differences within and between study populations by year of enrollment.

progress (Nettles, 1991). According to a 1994 study (Knowles & Harleston, 1997) [24] that collected data through interviews with IHE presidents, provosts, other administrators, and faculty and URM students at 11 elite research universities:

> *The availability of support throughout the doctoral program increases the probability that students of color will finish in a timely fashion. Indeed it is the experience of most institutions that as long as financial support is predictable and stable, there are no differences between minority and non-minority students in their rate of progress toward the degree or in attrition. However, as uncertainty about financial support is reduced after the first four years, the time to completion and/or the probability of attrition decreases disproportionately for students of color, who often have greater financial need* (pp. 11-12).

An NSF-sponsored research study appears to confirm further that financial concerns affect educational persistence. The researchers conducted an exploratory study to identify possible explanations of why capable individuals from underrepresented backgrounds decide to forego graduate study in favor of other pursuits. In-depth interviews revealed students' concerns about their ability to finance schooling. They were already paying loans used to finance their undergraduate education and they were reluctant to take on even more debt (Brazziel & Brazziel, 2001). Others have found that students with debt of $5,000 or more after they complete their undergraduate education are less likely to apply to graduate or first professional school than students without undergraduate debt (Millet, 2003). According to a panel of stakeholders[25] that convened during a workshop sponsored by NSF, NIH, and the Council of Graduate Schools, access to adequate, affordable health care coverage is another financial concern and is an essential factor in students' decisions to pursue a STEM graduate or post-doctoral education (Barnhill & Stanzione, 2004).

Admissions policies and practices

In graduate school admissions, some evidence indicates that IHEs have historically made efforts to increase the participation of URMs in their graduate programs by paying considerable attention to the demographic composition of the applicant pool and to the makeup of the admitted group of students. A study (1990-1991) analyzing applications and admissions data from 48 leading IHEs for five disciplines (biochemistry, economics, English, mathematics, and mechanical engineering) found that "substantial preference" was given to URMs over other U.S. citizens in graduate school admissions decisions (Attiyeh & Attiyeh, 1997). However, more recent reports indicate that graduate admission offices are beginning to encounter the same opposition to their policies and practices as those faced by their undergraduate counterparts

[24] The Ford Foundation sponsored this study to identify the barriers to increased diversity of the faculty at elite research IHEs: Columbia University, Duke University, Harvard University, Princeton University, Stanford University, the University of California at Los Angeles, the University of Chicago, the University of Michigan, the University of Pennsylvania, the University of Texas, and Yale University. The American Council on Education administered this project and collected data through interviews with the president; the provost; other administrators having responsibility for, and interest in, faculty diversity; minority faculty members; and minority graduate students. The analyses included institutional data on minority faculty recruitment and retention, as well as minority graduate student recruitment and retention.

[25] The panel including members of the National Postdoc Association, the Council of Scientific Presidents, a group of graduate students, a group of Advancing Science Serving Society fellows, and a group of graduate deans.

(Cross, 2000). Additionally, this "preference" ideally would indicate great strides in the enrollment of URMs in graduate programs. However, despite this outreach in admissions, data continue to indicate that African Americans, Hispanics, Native Americans, and Pacific Islanders continue to be underrepresented in populations of graduate students.

Moreover, while research has found "striking consistency across racial and ethnic groups in the criteria used in selecting [doctoral programs) for application," findings also suggest "clear differences in the factors affecting the choice of school to attend" especially for Latino and African-American students (Bar, Wanat, & Gonzalez, 2007, p. 23). For example, Stanford University sponsored a study on the application process from the perspective of applicants to its biomedical sciences doctoral programs to gain a better understanding of the criteria URMs with multiple acceptance offers use to select the university to attend.[26] This study found that while school reputation, school location, and the characteristics of the specific graduate program were the most important factors for students of all races and ethnicity in their decisions about the schools to which they wanted to apply, URMs weighted factors differently than non-URM students when deciding which schools to actually attend once accepted (Bar et al, 2007). For URMs, interpersonal interactions with faculty during the application process was a key factor in their decision to attend Stanford, in particular whether they felt comfortable with the faculty members they met and whether they perceived faculty as "hospitable, helpful, and interested in the students" (Bar et al., 2007, p. 31). Although the research is limited, the findings suggest that admissions practices that facilitate positive interactions between faculty and applicants may help increase the enrollment of URMs.

> *"Latinos and Latinas who are people-oriented and gravitate toward family and community life find graduate school can be the least attractive, least friendly, and sometimes the coldest community they encounter in their entire educational experience" (Ibarra, 2000, p. 89).*

Educational experience and quality

The nature and culture of graduate-level education can also become an obstacle to retaining URM students in the STEM pipeline. Graduate education in STEM disciplines is largely about preparing for a research career. The commonly used Socratic or adversarial teaching approach can disengage students and lead to an unappealing educational experience. It can also lead URM students to believe that they are inadequately prepared for the coursework or are likely to fail, even if in reality they are doing well academically (Fogg, 2009).

Additionally, graduate work typically entails long, solitary hours in the library and laboratory and graduate programs traditionally lack some of the university-sponsored support structures more common in undergraduate programs including clubs, fraternities, and other organized student activities (Fogg, 2009). Moreover, due to the small numbers of URMs enrolled in graduate school, these students are often "too dispersed and too few in number to form their own

[26] The study analyzed data from two consecutive admission cohorts (2003 and 2004) to Stanford University's 12 doctoral programs within the biomedical sciences. The final study sample included 59 admitted students of varying racial and ethnic groups. Subjects were interviewed using a semi-structured interview script.

support groups" (Ibarra, 2000, p. 89). Latino students (and potentially other URMs) in particular may struggle with such an isolating academic and social environment. According to Ibarra (2000), "Latinos and Latinas who are people-oriented and gravitate toward family and community life find graduate school can be the least attractive, least friendly, and sometimes the coldest community they encounter in their entire educational experience" (p. 89).

When a student's ethnic identity and cultural values clash with the academic value system within a STEM department, the transition into graduate school can become even more challenging for the URM. For example, faculty who are not culturally sensitive often exacerbate the lack of support structures for URMs in graduate school. Indeed, Ibarra (2000) posits that URMs may be at a marked disadvantage in graduate school because of cultural differences that arise between them and faculty who are not of the same race or ethnicity. He suggests that, to be viewed as successful, graduate students "must not only emulate their professors but must identify with their discipline in a way that resembles ethnic group cohesiveness" (Ibarra, 2000, p. 87). This emulation can be very difficult for URMs (including women) who may have a different understanding of success and failure than faculty at a typical research university. Faculty tend to measure graduate students' motivation and intellect by how well the students do on standardized tests, how well they fit into the department, and the extent to which they are interested in the faculty member's own research agenda. In contrast, for URMs, "developing their intellect may be more important than demonstrating their brilliance, their research interests may not always coincide with the faculty's interests, and 'working hard' may have nothing to do with cutthroat competition and everything to do with collaboration and progress toward [an alternate] goal" (Ibarra, 2000, p. 88).

Social and academic integration

Similar to URMs at the undergraduate level, URMs at the graduate level also experience feelings of stereotype threat; physical, cultural, and intellectual isolation; benign neglect; and problematic popularity. Indeed, the adverse effects of stereotype threat have been noted in studies focused on graduate students as well as on undergraduate students. Through semi-structured interviews with 12 doctoral students identified as "high achievers" in the field of education, Antony and Taylor (2004) found that each of the students experienced stereotype threat in a variety of ways including in campus life, in classrooms, in journals and textbooks, and in their interactions with faculty. Additionally, in terms of "problematic popularity," some STEM doctoral students who are African American report that this is "an extra burden not carried by [their]…majority colleagues" (Chubin, 2007, p. 94). During interviews, they noted frustration with expectations that they be "trailblazers" and deal with race-related issues in their field rather than focus on their coursework and research (Chubin, 2007).

Even students who feel a responsibility to accept the burdens of "problematic popularity" can suffer. In practice, these students may be torn between diversity-related outreach and their own research agendas. For example, one research effort examined the experiences of 40 African-American doctoral science or engineering students receiving support from the Graduate Scholars Program of the David and Lucile Packard Foundation (Chubin, 2007).[27] This effort, which

[27] To enhance science participation among individuals who are African American, historically black colleges and universities nominate Packard scholars who must pursue doctoral degrees in engineering, mathematics, or the

consisted of group discussions with the participants, found that some students perceived an additional burden because they participate in their programs' outreach to potential students from underrepresented groups while their peers focus on their research agendas.

Faculty-student mentorship

The importance of student support systems on the persistence of URMs in graduate school may be an even more critical factor than in undergraduate education. Research indicates that student support systems intended to enhance academic and social integration are a key influence on students' decisions to complete an advanced degree and pursue post-doctoral employment. The support systems can also help offset some of the previously described challenges and obstacles URMs encounter in the transition to graduate school. As indicated above, while the transition into postsecondary education and beyond can be difficult for all students, it can be especially difficult for URMs who are attending a predominantly White institution and who are pursuing degrees in STEM disciplines. Student support systems can help URMs academically and socially integrate into the campus community and their discipline of study. Indeed, "[r]esearch has produced a consensus that a supportive learning community is critically important for the success of minority students in math and science" (Busch-Vishniac & Jarosz, 2007, p. 253).

One key element of a supportive learning environment is strong faculty mentoring. Effective mentoring relationships and positive faculty interactions can offset or eradicate negative feelings such as stereotype threat and lead to a more satisfactory educational experience for URMs. At the graduate level, faculty mentoring programs for URMs have demonstrated effectiveness by positively affecting students' educational aspirations and increasing their degree completion rates (Davidson & Foster-Johnson, 2001; Davis, 2008; Milner, 2004; Payton, 2004). For example, some have argued that:

> *The presence of a faculty mentor or faculty sponsor offers the student many advantages, both personal and academic. Access to an established scholar provides the student with opportunities to test new hypotheses and research plans, affording the student a decided edge in his or her development as a bona fide scholar" (Willie, Grady, & Hope, 1991, p. 78).*

Indeed, research finds that "graduate students and graduate degree recipients perceive their relationships with faculty and mentors to be the single most important aspect of their satisfaction and their successful completion of graduate programs" (Nettles, 1990, p. 497). Findings from a 2002 study that examined the mentoring component of the Committee on Institutional Cooperation's Summer Research Opportunities Program[28] suggest that mentors influenced several aspects of their protégés' lives including the individual, interpersonal, and extra-programmatic.[29] Researchers also found that the mentoring component helped prepare students

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sciences (The David and Lucile Packard Foundation). Each scholar receives a $20,000 stipend that the foundation renews annually if scholars make satisfactory annual progress.

[28] The SROP program is designed to expand the number of students from underrepresented groups who pursue graduate study and research careers, More information on the program is available at: http://www.cic.net/Home/Students/SROP/Introduction.aspx

[29] Mentoring promoted self-assessment, personal development, and acquisition of skills; and positively affected students' educational aspirations. It also helped socialize students into academic life and form long-lasting

for both graduate school and entrance into the professoriate, and that the program appeared to result in a positive shift in faculty attitudes regarding the potential of individuals who are underrepresented (Davis, 2008). Others have argued that positive faculty-student relationships can relieve stereotype threat and minority students' subjective performance burden, especially those "in which professors communicate expectations of exceptional rather than poor performance and offer feedback in the context of an encouraging relationship" (Charles et al., 2009, para. 12).

Given the perceived importance of having a mentor, available data on the graduate school experiences of minority students in STEM disciplines can be disheartening. In the largest study of doctoral students ever conducted, researchers surveyed more than 14,000 graduate students from 21 U.S. IHEs that grant the majority of doctoral degrees.[30] They found that 36 percent of students who were African American lacked a mentor, compared to 29 percent for students who were White (Nettles & Millett, 2006).[31] The former figure increased to 43 percent for doctoral students in science and mathematics.[32] Furthermore, in that same study, respondents who were African American and in the sciences and mathematics had lower perceptions of their social interactions with faculty. Frustration with doctoral mentoring was another key finding of the aforementioned conversations with 40 Packard scholars (Chubin, 2007). Specifically, some of these scholars shared that they sense some faculty attempt to prevent doctoral program completion—largely because of faculty concerns about their own careers. Faculty may be concerned about the potential competition new doctoral graduates pose because they are more knowledgeable of contemporary technology and research.

Moreover, new graduate students frequently encounter a tradition of "sink or swim," finding their major professor "distant and detached rather than encouraging and supportive" (Ibarra, 2000, p. 88). In such a tradition, professors engage in a "wait-and-see" approach, leaving students to fend for themselves until they prove they possess the capabilities necessary for success in graduate school. This "sink or swim" tradition may be especially problematic for URMs who could benefit from a more supportive environment. Indeed, faculty mentorship may be critically important to URMs because it introduces students to a discipline's culture and underwritten "rules" and helps them develop the identity of a mathematician, engineer, scientist, or other profession. Frequent interactions also provide more opportunities for faculty to develop relationships with students more fully before determining whether or not they are competent in the field (Herzig, 2004). Also, faculty members are more likely to invest their time in finding the necessary supports for a student who is struggling if they have developed a personal relationship with the student. In particular, Davidson and Foster-Johnson (2001) suggest successful mentoring relationships, especially at the doctoral level, help underrepresented minority students:

professional relationships. Mentors provided moral support and helped students address fears of failure or stereotype threat. Some participating students also expressed interest in mentoring and working in their communities following the program.

[30] The researchers used a purposive sampling design and six criteria to select the 21 universities, such as ranking by number of degrees granted, ranking by amount of Federal funding, and the number of doctoral degrees granted to minority students between 1989 and 1993.

[31] More than 9,000 doctoral students completed the survey, yielding a response rate of 70 percent.

[32] The study did not find noteworthy differences by race-ethnicity in other fields.

- Integrate into the department's culture,
- Establish professional and social networks,
- Develop core research competencies, and
- Secure post-graduation placement in the workforce.

A study focusing on doctoral student attrition appears to affirm the positive affect mentoring can have on student persistence. The study investigated the reported experiences of doctoral students who had abandoned their programs across four departments (Biology, English, Geology, and History) in one university. The findings show that "incompatible advising relationships, marked by lack of interaction, trust, and intellectual support, were the cause of much of the attrition in science departments" and that a mismatch in the student-advisor relationship was a major factor in most respondents' decision to withdraw from their program (Golde, 2005, p. 686). Furthermore, inadequate socialization during the graduate experience may have a long-term impact if it affects the career decisions of STEM degree-holding URMs. A negative experience while in academia may affect whether students choose to join the professoriate or pursue other careers (as discussed in greater detail in the section entitled, The Professoriate and Other Career Paths).

As these findings and other related literature suggest, adequate mentoring efforts must be strategic and follow best practice. In an "effective" mentoring relationship there is a personal connection between the mentor and mentee, one which goes beyond just academic and career counseling. In a study[33] examining the time-to-completion rates of doctoral students at one land-grant university, departmental orientation and advising were key factors promoting both high program completion rates and short time-to-degree, and the student-advisor relationship was a crucial factor (Ferrer de Valero, 2001). The participants who fell within the high-completion and short-time-to-degree cluster described their advisor relationship as not only academic, but also personal. They considered their advisor a friend, "a person who could help them not only in academic issues but also in personal matters" (Ferrer de Valero, 2001, p. 356). This finding indicates that a successful mentoring relationship needs to go beyond helping a student outline a plan of study and career path and suggests that "nurturance and support are more effective at promoting student success than professionalism and formality" (Ferrer de Valero, 2001, p. 361). A successful mentor supports students so they not only achieve academic success, but also effectively integrate into their university's social community and culture.

Because effective mentoring appears to require a degree of "personal" rapport between a mentor and a graduate student, some researchers have wondered whether mentorship relationships between individuals of the same race are important. One important aspect of mentoring is trust,

[33] For this study, the researcher determined completion rates by measuring the percentage of the 1986-1990 entering student cohorts who earned doctoral degrees by the end of the 1995 fall semester in one large research university. He calculated time-to-degree rates using the first graduate school enrollment date and the graduation date for those departments with more than four students in the entering cohort. He then grouped academic departments into four clusters according to the median time to degree: high completion-short time to degree, low completion-short time to degree, high completion-long time to degree, low completion-long time to degree. He then randomly selected two departments from each group within each cluster. By cluster, these included family and child development and chemical engineering, finance and aerospace engineering, chemistry and biochemistry, and physics and psychology. He also conducted semi-structured interviews with faculty and doctoral students.

which may be difficult to establish in a cross-racial mentoring relationship (Blake-Beard, Murrel, & Thomas, 2006). As Wilson (2000) summarizes, James Blackwell noted that URM faculty should provide “intrusive advising,” or frequent student contact to monitor the academic progress of students also from these groups. In practice, however, it would be impossible to pair all URMs with faculty mentors of the same race or ethnicity. Moreover, as previously noted, studies have shown that URMs often struggle with finding a mentor of any background, let alone one who shares the same cultural characteristics (Davidson & Foster-Johnson, 2001).

Other factors affecting graduate participation in science, technology, engineering, and mathematics

Other factors may affect the decisions of URMs to enroll in, pursue, and persist in doctoral and post-doctoral STEM careers. These influences have less to do with educational quality or experience, and more to do with personal and professional characteristics and individual concerns. Of course, these factors undeniably interact with, and are difficult to disentangle from, the aforementioned issues related to students’ educational experiences.

According to the interaction theoretical perspective[34], there are several related constructs that affect student persistence. These include student academic and social integration into the university community (as discussed earlier), faculty interaction (also already discussed), and student intentions and background characteristics (which the following paragraphs discuss) (Bean & Metzner, 1985; Pascarella & Terenzini, 1980; Tinto, as cited in McConnell, 1993).

External demands and responsibilities. Students often experience competing demands on their time, such as family and work (Tinto, as cited in Herzig, 2002). “Indeed, graduate students often feel the strain of juggling multiple roles, such as being a spouse, parent, and caregiver to an older parent, usually while bringing in very little income” (Fogg, 2009, para. 12). These external factors can serve as very real obstacles for students and can limit their opportunities to participate fully in the academic and research community. In a case study of one mathematics department, graduate students highlighted the pressures and stresses they experienced in trying to find a balance between commitment to their program and to other important aspects of their lives. Some stated that they could have completed their degree more quickly had they chosen to focus on their studies more, but that they were unwilling to make the necessary sacrifices (Herzig, 2002).

Females from underrepresented groups may especially feel pressure from trying to balance commitment to their institution with external commitments. Family responsibilities affect females to a greater degree than males; academics studying underrepresented populations in STEM fields have noted that academic and non-academic fields have tended not to accommodate females who put their science and engineering careers on hold to raise a family (Dix, 1987). Some women have reported leaving graduate school because of concerns about balancing the demands of doctoral studies and a career in the sciences with family life. Of those who do persist, many will often choose careers in industry versus academe, or opt to teach at small colleges instead of large research universities (Herzig, 2004).

[34] According to McConnell (1993), the interaction theoretical perspective dominated attrition research throughout the 1980s. The theory suggests that interactions (or the lack thereof) between students and their institutions affect student attrition and retention.

CCAWMSETD (2000) noted that these personal and professional concerns are not unfounded. Its report states that in the workplace, URMs often experience inadequate work and family life accommodation, unequal pay scales and advancement, and non-inclusive behaviors. Furthermore, women with children often encounter negative stereotypes: "faculty may label a female student as being less committed to her career if she tries to raise a family while in school, or faculty may negatively evaluate a woman simply because she might have children" (Long & Fox, 1995, p. 56). For females who are underrepresented (based on their race/ethnicity), these types of challenges and barriers may have an especially significant role in their academic persistence and career commitment (or lack thereof) because they are likely already battling obstacles associated with their racial/ethnic identity.

Differing levels of research productivity. Data also indicate that disparities in research productivity exist between White students and URMs. In a study that examined the differences in human capital and their effects upon doctoral students' experiences and achievement, the researchers found that science and mathematics students who were African American were less than half as likely as their peers in other racial groups (i.e. Asians, Hispanics, and Whites) to have published articles in academic journals and half as likely to submit papers for publication (Nettles & Millet, 1999).[35] A Nettles and Millet (2006) study also found that students who were African American and enrolled in mathematics or science programs were less likely to publish articles or to "have overall research productivity" compared to students who were White (p. 211).

Long and Fox (1995) note that "it is possible that the process by which resources are allocated to support productivity favor White men and disadvantage women and minorities" (p. 55). Whatever the reason for the disparity, the disparity itself is a cause for concern. Various forms of research productivity are strong indicators of whether students acquire the research skills necessary for a successful STEM career (Nettles & Millet, 1999). Moreover, "publication productivity" is typically an important way of recognizing an individual's contributions to scientific knowledge (Long & Fox, 1995). Without this productivity, underrepresented minority students can be at a disadvantage in graduate school and in the trajectory toward an academic career.

Dearth of professional role models. The lack of diversity among STEM academics and professionals is a clear theme in the literature. For example, participants in the NSF Fellows program have noted that scientists from African American, Hispanic, Native American, and Pacific Islander backgrounds are inadequately visible in professional organizations (NSF, 1996). Other authors have commented on the limited diversity among geoscientists including NSF principal investigators, reviewers, and panelists (Huntoon et al., 2005). This lack of racial/ethnic diversity in the STEM professoriate is especially problematic because it limits the role models and networking opportunities of URMs in these fields (NSF, 2005). Consequently, these individuals face additional challenges in their endeavors to continue along their STEM career paths.

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[35] Interestingly, this disparity was not evident for engineering students, where the differences among white, Asian, Hispanic and African-American students are much smaller and nearly non-existent.

SUMMARY

In summary, it is clear that URMs encounter myriad challenges and obstacles in their pursuit of an advanced degree in a STEM discipline. They encounter these barriers early in their academic careers and many do not persist in STEM beyond the elementary-secondary years. Those who do enroll in a STEM program of post-secondary study frequently experience feelings of isolation and alienation. These negative experiences are then exacerbated by a lack of culturally sensitive faculty interactions and a dearth of professional role models and positive mentoring relationships.

At the graduate school level, these phenomena can become more pronounced for URM students. URM graduate students often confront a lack of a student support system that is sensitive to their situation as minorities. As URMs, they may be particularly susceptible to stereotype threat and inadequate mentorship. Like all graduate students, they must deal with the burdens of juggling personal responsibilities and school. These factors can all negatively affect a student's commitment to his/her educational goals and academic program.

There are additional external factors that can be hurdles in a URM graduate student's march toward completion of a PhD. The legal climate in some states has limited the degree to which institutions of higher education can implement outreach and support systems that are specific to racial and ethnic minorities. These limitations can undermine efforts to address the special situational needs of URM students and may consequently contribute to lower enrollments and higher attrition rates for URM graduate students. And finally, fluctuations in an educational institution's ability to help graduate students finance their educations can be a significant obstacle for all graduate students, and particularly for URMs. The literature shows that graduate students are in particular need for external support for tuition, fellowships and support programming. Disruptions of this stability—either through economic glitches at an academic institution or through hiccoughs in external funding—can hamper academic success.

These factors can also affect students' career plans and their pathways into the workforce. The more dissatisfied or concerned students are about their non-education responsibilities and their future opportunities for success, the less likely they are to persist in an advanced degree program.

CHAPTER IV: SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS ATTACHMENT: THE PROFESSORIATE AND OTHER CAREER PATHS

This chapter examines the decisions of URMs to enter the STEM professoriate or other careers. Specifically, it explores barriers to URMs' attachment to STEM careers. It begins with concerns related to socialization to career-related rewards, followed by a discussion of the attractiveness of STEM careers. The chapter ends with a discussion of the attractiveness of non-academic career opportunities and issues pertinent to doctorate holders' career decisions.

STUDENTS' SOCIALIZATION INTO CAREER-RELATED REWARDS

Uncertainty about finding a suitable professional position is a principal concern of students when deciding whether or not to pursue a STEM career (Barnhill & Stanzione, 2004). As indicated earlier, the choice to pursue a career in a STEM field (like the choice to pursue an advanced degree in STEM) is difficult for URMs because of the multiple obstacles faced along the pathway to a STEM career. For example, in the case of "women of color," gender and racial/ethnic research shows that the women may not select math-related or science careers for a range of reasons such as sex stereotyping in these fields, socialization toward other careers, negative or inadequate perceptions about these occupations, and a lack of role models (Clewell & Anderson, 1991). The literature also suggests that to opt for a STEM career, students generally must have adequately enjoyed their social and academic experiences to remain interested enough to engage in postdoctoral STEM work. The barriers and challenges discussed earlier may limit the exposure of URMs to STEM professoriate and other career opportunities. These obstacles may also engender negative perceptions or misunderstandings about the careers and activities of scientists, technicians, engineers, and mathematicians.

> *"Women of color are discouraged from pursuing math and science careers because they lack career information and role models, receive little or no encouragement from parents, teachers, and counselors to pursue "non-traditional" careers, and are confronted by the view that these fields are white male domains; women …of color still are socialized for social and service oriented careers" (Clewell & Anderson, 1991, p. 70).*

Students may also have misconceptions or false impressions about the job market in their field of study, or the types of employment opportunities available to them and the associated rewards—especially positions in academe. Although there has been progress at the undergraduate and master's levels to socialize URMs more effectively into the benefits of graduating from a science and engineering program, the same level of progress has not been evident at the doctoral level (Brazziel & Brazziel, 2001). For example, whereas undergraduates typically have access to pre-med and pre-law clubs or advisors, these support systems are typically unavailable to aspiring university researchers and professors (Knowles & Harleston, 1997).

Students from underrepresented backgrounds may also be torn between cultivating a professional persona—which is often shaped by White models—and their perceptions of remaining true to their ethnic or racial backgrounds. While not speaking solely about students from STEM graduate programs, Geneva Gay (2004) shares some additional insight about faculty from underrepresented backgrounds:

> *Recognition and visibility are important issues in the lives of professors of color. Graduate students should begin to deal with them during their doctoral studies. They can benefit from adding components to their graduate programs that focus on…"living in academe without losing your cultural and ethnic self"* (p. 285).

Conversely, a failure to develop this skill may undermine students' professional success.

ATTRACTIVENESS OF THE PROFESSORIATE

Individuals deciding whether to enter the professoriate or pursue another STEM-related career path undoubtedly experience similar concerns about their career options, regardless of their race/ethnicity. These concerns may include economic and social pressures, including finding a career that allows for a desired work/family balance. However, as a previous section explores, students from underrepresented backgrounds—those "of color"—often experience feelings of marginalization due to academic environments and support systems that lack cultural relevance. These feelings of cultural marginalization can remain with these students and may have a lasting effect on their postdoctoral decisions as they embark on and persist in, or depart from, their career paths (Gay, 2004). Marginalization is particularly problematic because, although the PhD is a terminal degree, one or two postdoctoral appointments are often necessary before scientists can become professionally employed. Although some post-doc opportunities are advertised in professional journals, others are granted more informally, learned about through word of mouth. Marginalized graduate students may lack this information network (Smith, Wolf, & Busenberg, 1996).

> *"No one gets a job after their PhD unless they want to teach in a community or a third-rate state institution. If you did, you wouldn't get funding for your lab. The National Science Foundation or some other funding agency wants to fund someone who has had some experience. …When you finish your PhD, you are expected to do a postdoc. Even then it is hard to find a job." (Smith et al., p. 96).*
> *–A Chicano neuroscientist*

The literature suggests that students will more likely dismiss previous notions of joining the professoriate if they have negative or indifferent experiences with their own professors, or if through their limited interactions they have a sense that faculty life is purely "work-centered" and "unbalanced" (Golde, 2005).[36] In some cases, individuals may forego academic careers because of the aforementioned experiences related to stereotype threat (Antony & Taylor, 2004).

[36] Golde's research uses data on enrolled doctoral students in four of the largest departments (biology, English, geology, and history) in the school of arts and sciences at a large, top-ranked research university over a five-year period.

Students may experience "disidentification" and no longer identify with their initial career goals because of stereotypes in their academic programs (Steele, 1997).

The American Association for the Advancement of Science reviewed more than 150 research studies on STEM student and faculty diversity, including the paths of URMs from STEM doctoral to postdoctoral positions, as well as to tenure and non-tenure positions in the professoriate (George et al., 2001). The studies focusing on the professoriate found that URMs experienced unique challenges relative to their advancement and retention in post-doctoral and tenure track faculty positions. These included, for example, fewer interactions with faculty peers and the lack of an influential mentor. "The issue of isolation goes beyond the debilitating effects of lack of social interaction," though: "one of the biggest problems that minorities…face is that they are excluded from full participation in the informal life of science (Etzkowitz, 2000, p. 299).

"Barriers to advancement and retention of URMs in post-doctoral and tenure track faculty positions include:

- *Fewer interactions with faculty peers*
- *A belief that they were hired because of affirmative action and not for their capability to do science.*
- *Lack of an influential mentor or sponsor.*
- *Difficulty with securing grants, even with a track record for high-quality research" (George et al., 2001, p. 9).*

CCAWMSETD (2000) has noted two primary factors that affect the advancement of underrepresented individuals into the ranks of the professoriate: interactions with faculty members and an IHE's racial climate. Relative to the former, "too many white faculty continue to believe that underrepresented minority faculty were hired because of affirmative action regulations and not on merits….and that the presence of more than one underrepresented minority faculty member in a traditionally mainstream program will lower the academic standing of the department (dubbed the 'one-minority-per-pot syndrome')" (CCAWMSETD, 2000, p. 56). Because of this sentiment, URMs who hold STEM faculty positions may experience an unrewarding work environment. The Commission also noted that poor racial climate, which the lack of mentors exacerbates, diminishes research productivity and subsequently hinders advancement in the professoriate.

In professional life, underrepresented minorities are often faced with inadequate work and family life accommodation, unequal pay scales and advancement, and non-inclusive behaviors in the workplace (CCAWMSETD, 2000).

Shirley Vining Brown explores several issues related to URMs on science and engineering faculty. She notes that although there is a limited body of information about their experiences, some research points to the unique experiences of URMs and illustrates how the professional climate in STEM academic environments may be alienating and unwelcoming to them. For example, beyond the limited representation among STEM faculty, faculty from underrepresented groups "have not achieved parity with white faculty in academic rank, range of work activity, or earning power" (Brown, 2000, p. 247). Moreover, those URM faculty members in traditionally

White IHEs often believe that they cannot attain their professional goals or develop acceptable relationships with other faculty members who are White.

The professoriate and other STEM careers may be unattractive to URM students for a number of reasons beyond the possible cultural and professional marginalization that the careers may entail. Other concerns that URMs and other students share include the anticipation of long apprenticeships with inadequate compensation and uncertainty about finding an autonomous research position once training is complete (Zumeta & Raveling, 2002). Additional issues include inadequate financial resources to support lengthy periods of education, lack of mentorship within academic departments, lack of encouragement to publish their research and other academic work in scholarly journals, and inadequate support from program faculty (CEOSE, 2004).

Researchers analyzing 1990 and 2000 U.S. Census Bureau data have found that market factors, such as the greater attractiveness of non-academic employment—because of perceived higher social status or higher earning potential—have a greater impact on participation in the professoriate (across all fields) for African Americans, Hispanics, and Native Americans than they do for students who are White (Turner, Viernes & Myers, 2000). The researchers conclude that the underrepresentation of individuals from these backgrounds in the professoriate is only partly explained by the undersupply of doctoral degrees among these groups.

> *Pursuing a science career should not be a matter of choosing hardship and sacrifice. In addition to interesting and challenging work, science careers should offer a strong support network, the possibility of having a real family life, an income throughout the careers that allows a comfortable family lifestyle, and possibilities for continuous advancement and development. Currently, many scientists feel that science careers are falling short in one or more of these dimensions, both in absolute terms and in relation to alternative careers that are attracting bright and talented young men and women"* (Preston, 2004, para. 25).

According to one survey that follows the careers of individuals completing undergraduate or graduate degrees from a large public university between 1965 and 1990, individuals leave the science workforce for four major reasons. These include unacceptable earnings and employment opportunities, inability to combine family with a scientific career, inadequate mentoring, and misalignment between interests and scientific job requirements (Preston, 2004). Temporary exits from the field can also lead to a permanent departure; the fast-paced changes in scientific knowledge can lead to a concomitant decrease in a doctorate-holder's skills because during the "temporary" exit the skills are not used (Preston, 2004).

Another study examined the extent to which high-achieving minority students receiving their bachelor's degrees in the arts and sciences selected the professoriate as their first-choice career.[37] Although not specific to students in STEM undergraduate programs, the study found that only 58 percent of students interested in entering the professoriate indicated they would continue to

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[37] The study included 7,612 students from 34 colleges and universities including the eight Ivy League institutions; 13 highly selective liberal arts colleges; nine large, less selective state universities; and four historically black universities (HBUs). For the state universities and HBUs, the study excluded students with grade point averages below 2.8.

graduate school within the year following undergraduate completion. The authors also found that "the proportion of [URM] students wanting to become academics is highest in the physical sciences and the humanities; is lower in mathematics, computer science, and the biological sciences; and is lowest in the social sciences" (Cole & Barber, 2003, p. 255). As part of their conclusions, the authors note that high-achieving students' career choice as freshman is the strongest predictor of their career choice as graduating seniors (Cole & Barber, 2003).[38]

In 1996, six recipients of the National Science Foundation Minority Postdoctoral Research Fellowship described issues related to underrepresented scientists' education and career development based on their experiences within the program (NSF, 1996). When discussing employment concerns, these fellows echoed a core theme: mentoring. At the postdoctoral level, mentoring is critical and can benefit individuals in various ways, including guidance on how to effectively develop a curriculum vitae, develop a scientific niche and market one's skills, establish and manage a research lab, identify and pursue employment opportunities, review manuscripts, and write grant proposals. Furthermore, for these fellows, participation in the NSF's program provided access to prestigious labs, fostering pathways to other opportunities.

The American Association of Colleges and Universities also studied the experience of minority scholars[39] who recently earned doctorates in a range of fields. Of the 299 interviews the researchers conducted, 20 percent were with scholars in engineering and science fields including biology, chemistry, geology, and physics. The researchers found that "there is a clear disjunction between the continuing national efforts to increase the numbers of women and minorities entering the science fields and the opportunities currently available to them when they complete their education" (Smith et al., p. 112).

ATTRACTIVENESS OF NON-ACADEMIC CAREER OPPORTUNITIES

Students in STEM graduate programs may have limited information about STEM careers outside of academe (CEOSE, 2004). However, for those who obtain this information, non-academic careers may be more attractive than the professoriate because of the former's higher salaries and greater social status, especially for individuals from underrepresented backgrounds who already face some of the aforementioned obstacles to careers in academia (as indicated by Turner, Viernes & Myers, 2000). Indeed, institutions of higher education increasingly find that some of their brightest students who are Black, Hispanic, or Native American are opting for corporate work in lieu of completing doctoral study. Moreover, perceptions that the job market within academia is limited may lead students to pursue what they perceive to be viable career alternatives; these careers may be those that require a lesser degree than a Ph.D. or that allow for an easy transition into the career with a master's degree (Golde, 2005).

[38] Of those graduating seniors who selected the professoriate as their career choice as graduating seniors, 70 percent had made this choice as a freshman.
[39] These scholars completed their doctoral programs between 1989 and 1995 and participated in one of three fellowship programs: Andrew W. Mellon Foundation, Ford Foundation, and the Spencer Foundation.

Careers outside the professoriate also yield challenges, though. For example, one empirical study of racial differences in career attainment and mobility among engineers concluded that "well-educated minorities have not been able to reap the benefit of their education and skills in the reward structure" and that minority engineers wanting to enter the "managerial ranks…may want to re-evaluate their career objectives (Tang, 2000, p. 198). Hence, these concerns may also influence the career trajectories of otherwise able and talented minority students.

SUMMARY

In summary, individuals entering or continuing in the STEM professoriate and larger workforce undoubtedly encounter similar challenges regardless of their race/ethnicity. These may include economic and social (family) pressures. However, URM students may also experience marginalization because of academic environments and support systems that lack cultural relevance. For females from URM backgrounds, these issues can be even more pronounced. Women of color confront sex stereotyping in STEM fields and face a dearth of role models and gender sensitive networks in addition to the barriers they face as representatives of URM groups.

Professional and cultural marginalization follows some URMs and affects their careers in all academic environments; the marginalization can be a significant concern as doctoral graduates embark on and persist in their careers. Some may consequently abandon dreams of the professoriate. Because they often lack mentors, these students may have misconceptions or false impressions about the job market for their field of study, or the types of employment opportunities available to them and the associated rewards—especially positions in academe. The small numbers of URMs in academic positions therefore becomes a vicious cycle that can perpetuate itself. Moreover, students in STEM graduate programs may have limited information about STEM careers outside of academe. For those who attain this information, non-academic careers may be more attractive than academe because the non-academic careers offer higher salaries and greater social status.

CHAPTER V: KEY THEMES

This literature review identifies several challenges and barriers that influence the doctoral and post-doctoral participation and persistence of URMs in STEM fields of study and, subsequently, the professoriate and other STEM careers. The salient themes include the following:

Pre-Graduate School

- ***Early pathway entry points.*** Individuals from underrepresented racial/ethnic groups are disadvantaged early in their academic careers, especially those from low socio-economic backgrounds. They typically attend public schools with limited access to high-quality mathematics and science teachers, curricula, and labs. Media representations, teachers with low expectations, and other social and cultural pressures often discourage URMs from pursuing mathematics- and science-related courses of study and careers.
- ***Undergraduate educational experience and quality.*** The literature suggests that the overall educational experience at the undergraduate level further affects the doctoral and post-doctoral plans of underrepresented individuals. Students who have negative feelings about their academic and social environments are less likely to pursue advanced study. Unfortunately, at the undergraduate level typical research universities do not practice innovative pedagogical practices that promote inquiry-based and active learning techniques as part of their undergraduate curricula. Instead, they use a process by which rigorous, lecture-based math and science courses are used to "weed out" students who may not have the potential to succeed in STEM fields of study.

Graduate School

- ***Educational affordability.*** URMs are frequently denied access to advanced degrees of study because of the high costs associated with pursuing an advanced STEM degree. Research suggests that a major reason students decide to forego graduate study for viable and potentially more lucrative alternatives is concern about financing their continued schooling, especially if they are already paying off loans used to support their undergraduate education.
- ***Admissions practices and policies.*** Universities and colleges have undertaken efforts to increase the participation of individuals who are underrepresented; however, despite these efforts, African-American, Hispanic, and Native American students remain a small proportion of the overall STEM graduate student population. Furthermore, the growing trend away from affirmative action admissions policies may serve as an additional hindrance to the participation of underrepresented individuals in science, technology, engineering, and mathematics. This trend may also lead to the elimination of other university programs aimed at supporting and integrating nontraditional students into campus life.

Graduate school typically entails long, solitary hours in the library or laboratory, and graduate programs tend to lack some of the support structures more common in undergraduate programs. It has been argued that these practices differentially affect individuals who are underrepresented and lead to higher attrition rates. These differential impacts are discussed below:

- ***Student support systems.*** As graduate students, URMs may also lack sufficient student support systems to help them integrate academically and socially into their department and introduce them to the rewards of doctoral and post-doctoral work. The absence of such systems can lead to feelings of isolation, frustration, and marginalization. Mentoring programs may help offset or alleviate these feelings; however, fulfilling mentoring relationships are frequently not enjoyed by URMs.
- ***External demands and responsibilities.*** Students' decisions to pursue and persist in STEM doctoral and post-doctoral work are also affected by individual characteristics and concerns such as commitment to the university and concerns about balancing life in academe with other responsibilities. Students may also be concerned about the possibility of their future success. Studies suggest that disparities in this area continue to exist for minorities, both in academe and the larger workplace. All of these factors can affect a student's commitment to his/her educational goals and the institution.
- ***The professoriate and the workforce.*** Individuals entering or continuing in the STEM professoriate and larger workforce undoubtedly encounter similar challenges regardless of their race/ethnicity. These may include economic and social (family) pressures. However, URM students may also experience marginalization because of academic environments and support systems that lack cultural relevance. Professional and cultural marginalization follows some URMs and affects their careers in all academic environments; the marginalization can be a significant concern as doctoral graduates embark on and persist in their careers. Some may abandon dreams of the professoriate as a result. Unfortunately, the lack of racial/ethnic diversity in STEM academic departments can limit the number of role models and networking opportunities for many individuals from underrepresented backgrounds. Because they often lack mentors, these students may have misconceptions or false impressions about the job market for their field of study, or the types of employment opportunities available to them and the associated rewards—especially positions in academe. The small numbers of URMs in academic positions therefore becomes a vicious cycle that can perpetuate itself.

  The literature suggests that students will more likely dismiss previous notions of joining the professoriate if they have negative or indifferent experiences with their own professors. Furthermore, URMs experience unique challenges relative to their advancement and retention in post-doctoral and tenure track faculty positions such as fewer interactions with faculty peers. STEM academic careers may be unattractive to students from underrepresented groups for a number of reasons beyond cultural marginalization, including anticipated length of apprenticeships with inadequate compensation and uncertainty that they will have autonomous research positions once training is complete. Moreover, students in STEM graduate programs may have limited information about STEM careers outside of academe. For those who attain this information, non-academic careers may be more attractive than academe because of their higher salaries and greater social status.

CHAPTER VI: IMPLICATIONS FOR THE NATIONAL ALLIANCES FOR GRADUATE EDUCATION AND THE PROFESSORIATE EVALUATION

The previous chapters indicate that increasing the number of URMs who pursue doctoral degrees in STEM disciplines is a nuanced issue with important national implications. Contemporary reports about the changes in American demographics suggest that, in the years ahead, a growing percentage of the U.S. population will be made up of the people collectively known as "minorities." Yet because of factors enumerated in earlier chapters, these URMs as a group are very unlikely to pursue, let alone complete, advanced degrees in STEM disciplines. The unlikelihood that many URMs will pursue advanced degrees has disturbing implications for not only the URMs individually, but for the nation as a whole. Reports about the future needs of the American workforce suggest that as a nation, the U.S. needs to increase the number of people who are highly trained in STEM disciplines. Without increasing the number of URMs who pursue advanced degrees in STEM, the nation's future economy may be underprepared for the fierce international economic competition and further innovation in which advanced education in STEM will be of paramount importance. Furthermore, URMs, who at present are disproportionately burdened by poverty and inadequate access to a strong education in STEM fields, will bear even greater economic and educational disadvantages.

AGEP-- a program specifically designed to increase the number of URMs who are pursuing advanced degrees in STEM disciplines and entering the STEM professoriate—can clearly address this concern. This literature review, as part of the national evaluation of AGEP's efficacy, is intended to inform exploration of the degree to which AGEP is helping URMs overcome obstacles specified in the literature. For example, because obstacles appear along several points in an individual's pathway to doctoral completion and the professoriate (e.g., URMs' weak preparation in STEM fields at the elementary and secondary school levels, or their loss of interest in STEM because of alienating pedagogical or professional practices at the collegiate level), the evaluation is gathering data on students' educational experiences and impressions, both early in their academic career and in graduate school. Moreover, to get a fuller understanding of students' experiences, the evaluation is using interviews, focus groups, and surveys to gather data on the perceptions of AGEP participating faculty about the students' educational experiences.

The literature shows that having an undergraduate research experience can influence URMs' likelihood of pursuing an advanced degree in STEM. Consequently, surveys in the evaluation are capturing information on the extent to which current doctoral candidates have had such experiences. In our site visits and in our surveys, we ask whether AGEP's support of such experiences has, in fact, influenced URM students' academic and career trajectories.

The literature also underscores how attitudinal and sociological factors can influence URM students' success in STEM fields. Combating social isolation while in undergraduate and graduate school, overcoming stereotype anxiety, and surpassing the low expectations held by some of their faculty members and non-URM peers are issues that need to be addressed in working toward URM success in STEM. In our site visits and in our surveys, we ask current and some former URM students about these issues, and determine whether AGEP-supported activities in any way mitigate the burdens associated with the issues. To gauge the supportiveness of AGEP campuses' academic climates, the study is gathering pointed information from faculty members and campus staff who participate in AGEP activities. In interviews, focus groups, and surveys, these groups are being asked questions that might elucidate the degree to which attitudinal and sociological obstacles to URMs' success persist and the degree to which AGEP-funded projects help reduce the obstacles URMs encounter.

Finally, the literature indicates that beyond the factors already mentioned, there are many other factors that influence students' choices about study and career. These factors include balancing work and family, a need for greater salary and social status than an academic career may provide. Many of these factors are not specific to any particular racial or ethnic group. The AGEP evaluation is therefore gathering information from current AGEP students as to the degree to which these factors have influenced the students' decisions about study and career.

AGEP and the Professoriate

Beyond getting URM students to pursue PhDs in STEM disciplines, AGEP seeks to increase the number of URMs who complete PhDs and enter the professoriate. As professors, these URMs can serve as role models to subsequent generations of students—URM and non-URM. Once in academia, these individuals can serve as the primer for a greater flow of URMs into STEM positions. For instance, the literature emphasizes that students need effective mentorship, and further indicates that URMs frequently lack such mentors, either because of perceived cultural barriers between them and non-URM faculty, faculty indifference, or the lack of approachable role models. An increase of URM faculty in the STEM professoriate can address this problem.

In some cases, the URMs who enter the professoriate with AGEP support may also engage in research that is particularly germane to some URM communities. This phenomenon, in turn, can pique the curiosity and interest of URMs who might otherwise feel distanced from STEM fields. In some cases, but obviously not all, these professors may take a special interest in seeing more members of their respective communities pursue advanced STEM degrees, and may make special efforts to increase the flow of URMs in the STEM educational pipeline. These are all implicit goals of the AGEP program, and the evaluation is looking for indications that in increasing the number of URMs who enter the professoriate, the program is in some way addressing these goals. As AGEP matures as a program, the evaluation may eventually seek to determine the degree to which the presence of these URM professors has in any way affected the experiences of subsequent cohorts of AGEP students.

The AGEP evaluation will gather data on many of these factors—in the context of URMs, but also with the greater goal of helping all students. By focusing on URMs, AGEP seeks to provide opportunities to students who the STEM fields have historically underserved. In doing so, however, the program seeks not only to build diversity in STEM but also to support the nation's future economic and educational needs.

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APPENDIX A: LITERATURE REVIEW METHODS

An initial part of the search strategy entailed a thorough search of online databases, including ERIC and JSTOR, as well as STEM-related websites and industry-specific journals. For example, these included:

- American Association for the Advancement of Science,
- American Council on Competitiveness,
- American Educational Research Association (AERA),
- Association for the Study of Higher Education (ASHE),
- Centers for Study of Higher Education,
- *Educational Research Journal*,
- Google Scholar,
- National Academy of Engineering,
- National Academy of Sciences,
- National Association of Black Engineers,
- National Institute of Health (NIH) Office of Minority Programs,
- National Science Foundation,
- PEW Charitable Trusts,
- Society of Hispanic Engineers, and
- Society of Hispanic Professional Engineers.

We used combinations of the following key search terms to identify relevant sources of information:

- Doctoral education
- Science, technology, engineering, mathematics
- Underrepresented minorities
- Retention,
- Completion
- Doctoral pathways
- STEM pipeline

This initial search resulted in more than 300 references. A review of the results suggested that the search terms were appropriate and were largely yielding sources of interest. The full list of identified sources was then reduced to approximately 80 books, articles, and reports. Six team members took part in the process of summarizing articles, with each team member assigned several of the identified sources to review and summarize. Reviewers used an established template to complete their reviews. For each source, staff recorded the following information:

- Whether the reference was research or theoretical based and/or policy related
- The research design and methodology, if applicable
- Relevant key words
- A summary of the reference
- Key findings or arguments
- Recommendations, if any

We used the summaries to facilitate the writing process and prior to that, to ensure we were not missing literature on an important area of interest. We accomplished this by doing a preliminary review of the summaries alongside the literature review outline. The sources were mapped to the major sections of the outline and any apparent gaps were identified. Project management held weekly meetings with staff throughout the review process to track the progress of the reviews, to ensure the identified sources were appropriate for the focus of the literature review, and to identify any sources that could be eliminated or added. For example, those sources that focused more on the general population of students as opposed to students who are underrepresented, or those that focused primarily on disciplines of study outside of STEM were dropped. Also, project staff was careful to review the bibliographies and works cited lists of the identified books and articles to identify other pertinent and relevant sources and studies that should be included. When possible, we accessed sources online. We ordered sources unavailable online through AIR's Interlibrary Loan program.

Senior staff conducted a quality check of the reference summaries for each reviewer. At least two full references were read alongside the completed summaries to ensure the information in the template was accurately documented. We used the *Reference Manager* software program to further support the review process and manage the bibliography. *Reference Manager* served as a database of the literature, storing the completed summaries, keywords, and bibliographical information of each source.