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The Path to Graduate School in Science and Engineering for Underrepresented Students of Color

Marybeth Gasman  
*University of Pennsylvania, mgasman@gse.upenn.edu*

Laura W. Perna  
*University of Pennsylvania, lperna@gse.upenn.edu*

Susan Yoon

Noah D Drezner  
*University of Pennsylvania*

Valerie Lundy-Wagner

*See next page for additional authors*

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Abstract
Over the past decade, the number of Black, Hispanic, and American Indian/Alaska Native students attaining bachelor’s degrees in science and engineering fields has increased substantially. In 2004, 13.9% of all bachelor’s degrees in science and engineering fields were awarded to students from these three groups, up from 11.2% in 1995 (Hill & Green, 2007). Although Blacks, Hispanics, and American Indians continue to be underrepresented among bachelor’s degree recipients in science and engineering fields relative to their representation among all bachelor’s degree recipients (13.9% versus 16.9% in 2004, Hill & Green, 2007), these trends suggest that progress is being made.

Disciplines
Disability and Equity in Education | Education | Educational Administration and Supervision | Higher Education

Author(s)
Marybeth Gasman, Laura W. Perna, Susan Yoon, Noah D Drezner, Valerie Lundy-Wagner, Enakshi Bose, and Shannon Gary

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THE PATH TO GRADUATE SCHOOL IN SCIENCE AND ENGINEERING FOR UNDERREPRESENTED STUDENTS OF COLOR

Marybeth Gasman, Laura W. Perna, Susan Yoon, Noah D. Drezner, Valerie Lundy-Wagner, Enakshi Bose, and Shannon Gary

Over the past decade, the number of Black, Hispanic, and American Indian/Alaska Native students attaining bachelor’s degrees in science and engineering fields has increased substantially. In 2004, 13.9% of all bachelor’s degrees in science and engineering fields were awarded to students from these three groups, up from 11.2% in 1995 (Hill & Green, 2007). Although Blacks, Hispanics, and American Indians continue to be underrepresented among bachelor’s degree recipients in science and engineering fields relative to their representation among all bachelor’s degree recipients (13.9% versus 16.9% in 2004, Hill & Green, 2007), these trends suggest that progress is being made.

Less progress, and greater underrepresentation, is present at the master’s and doctoral degree levels. Table 4.1 shows that students from underrepresented minority groups (i.e., American Indians/Alaska Natives, Blacks, and Hispanics) received only 6.9% of all master’s degrees awarded in science and engineering in 2004 (up from 5.3% in 1995). Only 4.2% of all doctoral degrees in science and engineering were awarded to these students in 2004, a slight increase from the share awarded in 1995 (3.2%, Hill & Green, 2007).
<table>
<thead>
<tr>
<th>Degree and field</th>
<th>1995</th>
<th>2004</th>
<th>Underrepresented minorities</th>
<th>1995</th>
<th>% of total</th>
<th>Number</th>
<th>2004</th>
<th>% of total</th>
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</thead>
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<tr>
<td>Bachelor's degrees</td>
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<td>Science &amp; engineering</td>
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<td>All fields</td>
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<td>Science &amp; engineering</td>
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<td>75,399</td>
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<td>All fields</td>
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<td>42,155</td>
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<td>Science &amp; engineering</td>
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<td>18,808</td>
<td>623</td>
<td>3.2%</td>
<td>797</td>
<td>4.2%</td>
<td></td>
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</tbody>
</table>

Source: Hill & Green (2007).

Notes: “Science and engineering” includes the following fields: science (agricultural sciences; biological sciences; computer sciences; earth, atmospheric, and ocean sciences; mathematical sciences); physical sciences (astronomy; chemistry; physics; other physical sciences); and engineering (chemical engineering; civil engineering; electrical engineering; mechanical engineering; other engineering). Although the National Science Foundation also includes psychology and social sciences in “science and engineering” fields, we do not consider psychology and social sciences degrees in this category.

Underrepresented minorities are American Indians/Alaska Natives, Blacks, and Hispanics.
This decline in the representation of American Indians/Alaska Natives, Blacks, and Hispanics along the pathway from bachelor’s to doctoral degree completion in STEM (science, technology, engineering and mathematics) fields has important implications for the representation of these groups in STEM careers that require a doctoral degree, particularly college and university faculty positions. Thus, these data suggest that one critical mechanism for raising the representation of these groups among faculty in STEM careers is to improve their transition to and success in graduate school.

Degree attainment in science and engineering for Blacks, Hispanics, and American Indians/Alaska Natives is limited by the absence of appropriate preparatory courses, insufficient experiences with science-oriented activities, and a lack of same-race role models and mentors (Clark, 1988; Hanson, 1996; Leslie, McClure, & Oaxaca, 1998; Seymour & Hewitt, 1997).

This chapter describes how colleges and universities can promote graduate school enrollment and degree attainment for undergraduates from underrepresented groups in science; engineering; and, more broadly, STEM fields. Drawing on a comprehensive literature review, this chapter identifies four institutional approaches for improving the educational attainment of undergraduate students of color in STEM fields. It should be noted that the literature pertaining to students of color in the STEM fields is problematic in several ways. First, there are very few empirical studies. Instead, the articles tend to be personal accounts by both majority and minority faculty. Second, most of the articles related to this topic are relegated to journals pertaining to women and minorities. It is rare that an article can be found in a mainstream journal, leading us to speculate whether the topic and students of color themselves remain at the margins of the STEM fields. Third, most of the literature related to students of color in the STEM fields pertains to the undergraduate level, revealing a substantial gap in the literature at the graduate level. Finally, although the approaches discussed in this chapter are the most prevalent in the literature and have the most empirical support, there are other approaches that may be equally helpful to underrepresented students of color in STEM fields.

Traditional Approaches to STEM Education

Increasing the presence of students of color in STEM education can be framed as a social justice issue (Treisman, 1992). Because of past injustices committed against racial and ethnic minorities in this country, some faculty and administrators have believed that the nation has a moral obligation to provide opportunities to students of color. More recently, increasing the
educational attainment of Blacks, Hispanics, and American Indians in STEM fields has also become an institutional priority, both to create future faculty and researchers and, as an economic imperative, to create a competitive workforce in a global economy. This economic justification for increasing opportunities and attainment for students of color in STEM education appears to be more acceptable to those who are made uneasy by affirmative action or social justice rationales (Treisman, 1992).

Traditional approaches to STEM education emphasize “survival of the fittest.” Such approaches assume that the lack of attainment in STEM fields for underrepresented minorities is attributable to the students’ background characteristics, including socioeconomic status, parental education, family support, preparation in high school, and even genetics (Armstrong & Thompson, 2003; Elliot, Strenta, Adair, Matier, & Scott, 1996; Leslie et al., 1998; Seymour & Hewitt, 1997; Treisman, 1992). In short, these approaches attribute failure in STEM to student characteristics, leaving the institutional or cultural practices of colleges and universities largely free from blame and responsibility.

In contrast, more recent approaches emphasize the institutional role in empowering students by drawing on students’ strengths. Rather than questioning whether students of color can excel, these strategies focus on institutional changes that promote success in STEM fields for students of color (Hanson, 1996; Hanson & Johnson, 2000; Jordan, 1999; Treisman, 1992). However, myriad college and university STEM programs continue to assume that weeding out the weak is an optimal strategy (Seymour & Hewitt, 1997), despite the fact that a review of the research suggests that strategies that focus on empowering students of color in STEM are more effective than traditional approaches (Hanson & Johnson, 2000; Treisman, 1992). This chapter focuses on institutional strategies and approaches for empowering students of color to gain access to and complete graduate STEM programs.

Institutional Strategies for Promoting Attainment in STEM for Underrepresented Students of Color

Our review of available research suggests four institutional approaches for increasing access to and completion of graduate education for students from underrepresented minority groups: developing integrated support systems, ensuring inclusive curricula, promoting interactive classrooms, and increasing the availability of role models and mentoring.
Integrated Support Systems

One strategy for promoting the success of students of color in STEM graduate education is to develop an integrated support system. On many campuses, support programs for students in STEM are typically disconnected from the curriculum, for example, study skills workshops (Seymour & Hewitt, 1997; Treisman, 1992). One reason for this disconnect is that support programs are designed not by faculty but by administrators, who do not have an accurate understanding of course content or activities (Treisman, 1992). Consequently, most study skills programs are planned separately from the curriculum, with no consideration of the types of assignments given in classes. In effect, students are mastering skills that do little to promote their achievement in STEM classrooms and labs. Furthermore, the availability of other types of support programs—for example, tutoring in STEM fields—is insufficient to meet real needs (Seymour & Hewitt, 1997).

Treisman (1992) and Kane, Beals, Valeau, and Johnson (2004), based on their qualitative study, including observation and interviews, of Hartnell Community College, recommend that STEM faculty members at both the undergraduate and graduate levels work with academic advisers and program support systems to create student programs that address the kinds of assignments and exams given in STEM classes. These researchers also encourage the use of an early alert system, in which academic advisers and faculty identify students of color who are struggling academically. Identifying and addressing academic problems early in the program prevents students from falling behind and becoming disillusioned and overwhelmed with STEM education and may ultimately increase the number of students of color entering STEM graduate programs (Kane et al., 2004). Although the argument could be made that early identification of problems is important in any degree program, falling behind is particularly difficult in the STEM fields because of the steep learning curve and the sequential nature of learning as courses and assignments build on prior knowledge (Kane et al., 2004; Seymour & Hewitt, 1997). Moreover, falling behind during the undergraduate years makes it particularly difficult to pursue graduate study.

Compounding the problem of disconnected support systems is the low rate of usage of such systems by students of color and, in particular, Black and Hispanic students (Treisman, 1992). Research suggests that some students view support systems, especially those specifically for students of color, as remedial and inappropriate. Based on a qualitative study of African American and Latino students at the University of California at Berkeley, Treisman
(1992) describes how one such support system was viewed by these students. After being accepted to the university, students of color in STEM received a "welcome" letter that stated, "Dear Minority Student: Congratulations on your admission to Berkeley. Berkeley is a difficult institution. You are going to need a lot of help and we are here to help you" (Treisman, 1992, p. 367). Students typically ignored the letters, as many viewed them as insulting or degrading, given that most of the admitted Black and Hispanic students were academic leaders in their high schools and were viewed by their peers as role models. Thus, it is believed that the a priori assumption of low academic abilities affected students' self-esteem (Treisman, 1992).

In contrast, a more successful institutional strategy for increasing use of support systems by students of color is to establish nonremedial integrated support systems. Instead of merely providing tutoring, time management, and study skills, nonremedial support programs emphasize group learning driven by problem solving and a community life focused on a shared interest in STEM (Armstrong & Thompson, 2003; Kane et al., 2004; Treisman, 1992). These programs often invite all students, regardless of race/ethnicity, to participate, although programs in which students of color constitute a critical mass or a slight majority show the best outcomes for students of color (Treisman, 1992). For example, participating colleges and universities have found that through working with the Posse Foundation, an organization that organizes a critical mass of students of color to enroll at particular institutions and in particular majors, students are more successful and more likely to persist in college (www.possefoundation.org).

An integrated support system for students of color in STEM should also include attention to other university services, particularly housing and financial aid. Although STEM programs do not have administrative authority over such services, STEM administrators can work with administrators around the university to ensure that the academic progress of students of color in STEM is not derailed by housing, financial aid, and other nonacademic challenges (Armstrong & Thompson, 2003; Treisman, 1992). On the basis of an evaluation study using quantitative analyses, Armstrong and Thompson (2003) argue that STEM program faculty members and administrators need to "hasten students' acclimation to the university environment by introducing them to social, bureaucratic, and administrative hurdles that they must deal with as college students" (p. 161). For example, regardless of degree field, many Black, Hispanic, and American Indian/Alaska Native students are operating on extremely tight budgets and consequently depend on the timely posting of financial aid dollars to their accounts. In addition,
at least in part because of financial need, about three fourths of traditional-age undergraduates (regardless of race/ethnicity) work while they are enrolled (Perna, Li, & Cooper, in press). Many students hold off-campus jobs that require them to work on average about 24 hours per week (Perna et al., in press). Although the academic performance and progress of students in all fields may be impaired by working long hours while enrolled, the negative consequences may be greatest for students in STEM fields, given the stringent academic standards and performance requirements in these fields.

**Inclusive Curriculum**

A second institutional strategy for promoting access and success in graduate programs in STEM fields for students of color is creating an inclusive curriculum (Armstrong & Thompson, 2003; Green, 2001; Seymour & Hewitt, 1997; Tobias, 1992). Research shows that African Americans and Latinos, in particular, often feel alienated by and fearful of STEM education curricula (Anderson, 1990). The four main reasons that students of color find STEM classes disaffecting are the “gatekeeper” approach to learning, the scarcity of diverse perspectives in the curriculum, the perceived lack of social relevance of STEM course work, and the use of pedagogies that fail to engage students of color in STEM course work.

Many STEM education programs feel that “gatekeeping” is useful and necessary for guaranteeing quality control after the admission process. As such, programs typically use gatekeeper courses to “weed out” students during the first two or three years. At the beginning of such courses, the teacher usually lays out the *failure* parameters, and in such settings, cooperation among a few students does not evolve naturally but instead results from desperation (Anderson, 1990, p. 352). Gatekeeper courses “send a message to students that being admitted to the program is not enough” (Busch-Vishniac & Jarosz, 2004, p. 270). Students must continually work to justify their presence in the program, and as Busch-Vishniac and Jarosz (2004) suggest, “It is difficult to think of something more discouraging than these gatekeeper courses, both for the students taking the courses and for the faculty members teaching them” (p. 270).

For students of color, the gatekeeping rationale discourages them from pursuing STEM degrees in several ways. First, Blacks and Hispanics are less likely to risk rejection and failure than their White counterparts are (B uncick & Horgan, 2001; Busch-Vishniac & Jarosz, 2004; hooks, 1994; Treisman, 1992). Second, to survive these gatekeeping courses, many students form classroom work groups. While Whites and Asians often work together in groups, students of color are often excluded from these groups because of
their perceived inferior academic ability (Seymour & Hewitt, 1997). Finally, gatekeeping courses stress memorization over other forms of learning, particularly problem solving. Researchers who want to reform these crucial courses claim that there is a difference between a student’s ability to memorize and his or her ability to solve problems (Anderson, 1990). As solving problems is the modus operandi of science and math disciplines, it is the key to success in STEM courses and should be recognized in the classroom.

In addition to the issue of gatekeeping, a second reason that students of color find STEM classes to be disaffecting is the perception that STEM curricula are gender biased and Eurocentric (Anderson, 1990; Riley, 2003). Some critics argue that technical courses within the STEM fields “are known for their White male bias” (Busch-Vishniac & Jarosz, 2004, p. 261). Researchers have found that textbooks for these courses fail to consider the contributions of females, and when they do, they fail to name the contributors (Busch-Vishniac & Jarosz, 2004; Marshall & Dorward, 1997). Thus, even if the scientific discoveries are made by women, the scientific heroes are all men.

With regard to race and ethnicity, textbooks rarely identify authors by race and few faculty members mention race during class discussions (Anderson, 1990; Busch-Vishniac & Jarosz, 2004). As a result, faculty and students seldom discuss the historical influence of non-Western civilizations (e.g., African, Indian, Chinese, and Mayan) on STEM fields (Anderson, 1990; Riley, 2003).

“Decentering” Western civilization requires an examination of the history of science literature for examples (Riley, 2003). Diversifying the curriculum is possible, as ample information describes non-Western origins of astronomy, physics, math, chemistry, and fundamental ideas in engineering (Anderson, 1990). To address this need, some STEM faculty members include a history of their discipline in introductory classes to show the diverse origins of math and science. For example, in a calculus or physics class, students of color may be inspired by faculty efforts to “show how early mathematics and science led to the building of the pyramids, the Great Wall of China, and the road to Katmandu” (Anderson, 1990, p. 355). Efforts to create a more inclusive curriculum are designed to “shatter the myth” that STEM fields of study are a “White man’s thing” and to show students that “all civilizations, though they differ and develop at different paces, have always been bound inextricably to each other” (Anderson, 1990, p. 355).

The use of a curriculum that draws on the multifaceted history of the STEM fields is at the center of the success of many historically Black colleges and universities (Gasman, Baez, Drezner, Sedgwick, & Tudico, 2007). As such, these institutions are disproportionately successful in educating African
American students. For example, Xavier University of Louisiana, using a curriculum rooted in African American history and success, places 100 students in medical school each year (American Medical Association, 2005). This contribution is greater than that of any other institution in the United States and is especially impressive given Xavier’s minimal resources and meager endowment (Gasman, Baez, Drezner, et al., 2007).

A third reason that students of color find STEM courses to be alienating is the absence of clear social relevance. In addition to wanting to see themselves in the curriculum, students of color are looking for a curriculum that shows the impact of science on the larger world (Busch-Vishniac & Jarosz, 2004). Busch-Vishniac and Jarosz (2004) argue that students of color and women tend to choose majors that they see as clearly beneficial to society and that they think involve a high level of interaction with other people. Students of color are also interested in exploring issues that are relevant to their own racial or ethnic subgroup (Busch-Vishniac & Jarosz, 2004).

To make the curriculum more diverse, relevant, and engaging, STEM programs must retool the curriculum from the ground up. According to Busch-Vishniac and Jarosz (2004), “There has been a strong tendency to use minor changes and additions rather than wholesale revamping [of the curriculum] to achieve diversity. The result is not surprising. Gains are modest at best and cannot be sustained without constant diligence” (p. 256). The authors suggest revamping STEM curricula to emphasize the many examples of how STEM course content can be used to help humanity.

A final component of an inclusive curriculum is the use of pedagogical approaches that engage students of color in learning. Seymour and Hewitt (1997) stress the need to use teaching styles that are inclusive and that foster learning for diverse populations, stating, “The most effective way to improve retention among women and students of color, and to build their numbers over the longer term, is to improve the quality of the learning experience for all students—including non-science majors who wish to study science and mathematics as part of their overall education” (p. 394).

The most successful instructional reform efforts in STEM education show the value of connectivity, engagement, and inclusivity (Buncick & Horgan, 2001; Busch-Vishniac & Jarosz, 2004). Connectivity means that the curriculum makes links to students’ concrete life experiences (as noted earlier) and that the course concepts are not taught solely in isolation or in the abstract (Busch-Vishniac & Jarosz, 2004). In other words, connectivity requires an integrated curriculum and faculty attention to drawing connections between concepts. Engagement means that students do not sit passively in class but actively work with faculty or peers to solve real-life problems.
bell hooks's (1994) experience and research confirm the benefits of engagement. She found that women, in particular, are more engaged in learning when instructional techniques require action and collaboration rather than passive reception of knowledge. One way to promote engagement may be to require students to take fewer classes and to ensure that these classes provide a more in-depth approach to learning (Treisman, 1992). Group and collaborative learning opportunities may also promote engagement. On the basis of quantitative analyses and qualitative interviews with STEM undergraduate students, Seymour and Hewitt (1997) note that, although most students, regardless of race or gender, attach importance to collaborative learning and active engagement in the STEM classroom, students of color and women "sought-after, used, [and] appreciated" group learning more than other students (p. 174). Opportunities to talk and interact with other students helped the students of color to engage more closely with the course material (Seymour & Hewitt, 1997). As in the earlier discussion of diversity in the curriculum, inclusivity means that all students are actively engaged by the course material and the professor (Buncick & Horgan, 2001). By embracing a curriculum that encourages students of color to see themselves as future scientists, mathematicians, and engineers, programs increase the likelihood that students pursue graduate degrees in these fields (hooks, 1994; McKeachie & Svinicki, 2006).

Programs that adopt the three instructional approaches of connectivity, engagement, and inclusivity are better able to prepare students of color for graduate education in STEM. For example, at Eastern Illinois University, with the support of the National Science Foundation, administrators created a transfer degree program with a tribal college in Minnesota. The program aimed to increase the number of American Indian computer science and engineering bachelor's degree recipients by focusing on indigenous culture and tribal relevance and using a culturally based education model. Within two years of the program's inception, participating students were winning national computer science and engineering competitions and receiving competitive scholarships from agencies such as the National Aeronautics and Space Administration (NASA) (Busch-Vishniac & Jarosz, 2004).

Three-two programs (i.e., articulation agreements between two institutions) offer another model for addressing issues of connectivity, engagement, and inclusivity. Three-two programs acknowledge that students of color can benefit from the nurturing educational environments at historically Black colleges, tribal colleges, and women's colleges and that students attending these institutions can obtain a strong academic foundation in core math and
science classes (Gasman, Baez, Drezner, et al., 2007). Articulation agreements for three-two programs specify that students take the first two or three years of their studies—the time in which many drop out of STEM majors—at the nurturing liberal-arts-focused institution before moving to a larger, more technical institution to acquire discipline- and major-specific skills. Examples of institutions participating in these programs include Texas Women's University, Texas A&M University, Mills College, the University of Southern California, Morehouse College, Spelman College, and the Georgia Institute of Technology (Busch-Vishniac & Jarosz, 2004). Although these programs are, for the most part, at the undergraduate level, they are vital to success at the graduate level and typically act as an impetus for interest in graduate study.

**Interactive Classrooms**

A third institutional strategy for promoting access and attainment in STEM education for students of color is to shift the instructional culture from competitive to interactive. Several researchers observe that the undergraduate and graduate academic experience in science and engineering course work is typically competitive rather than collaborative (Armstrong & Thompson, 2003; Busch-Vishniac & Jarosz, 2004; Zhao, Carini, & Kuh, 2005). All too often, students in STEM courses see themselves in an adversarial relationship with their professors and in competition for good grades with their peers, especially because of curved-grading practices (Seymour & Hewitt, 1997). The typical STEM college classroom is designed so that individuals must "compete ruthlessly with each other for knowledge" (Anderson, 1990, p. 352). An emphasis on competition over collaboration is troubling because of the negative implications of this approach for both student persistence in STEM fields and student preparation for STEM careers. Most companies, especially those in science and technology fields, now want employees who can work in teams collaboratively (Busch-Vishniac & Jarosz, 2004). In addition, for women in particular, the perceived masculine culture of both STEM education and careers, with associated social and academic processes that, in addition to competition, stress the disconnected, objective rational pursuit of knowledge, conflicts with the preferred learning styles of women (which are typically more collaborative and situated), thus presenting further obstacles for access and success (Zhao et al., 2005).

When a few students, typically White males, dominate classrooms, other students may feel neglected and, worse yet, that they are not "right" for STEM fields, especially for future graduate study (Buncick & Horgan, 2001). To involve and support all students in STEM fields, Riley (2003)
argues for an "engaged pedagogy" that "respects students in the classroom as authorities" (p. 147). On the basis of her theoretically driven research, Riley claims that "creating a community of scholars in the classroom is the goal, and if students and instructors can each bring knowledge and experience to share, it demonstrates that students have valuable contributions to make and that everyone deserves to be heard" (p. 147). Drawing on the work of hooks (1994) and Freire (2000), Riley encourages the use of liberatory, feminist, and radical pedagogies to create democratic classrooms. Specifically, she recommends that students participate in teaching in the classroom, creating in-class activities for other students, using technology, and gathering supplemental materials for course lectures.

Anderson (1990), a math professor, also suggests alternative approaches to teaching STEM. In his opinion, the teacher should take on the role of confidence builder. For example, Anderson explicitly tells all his students that they begin with an A grade but must struggle to keep it. He believes that this strategy communicates the assumption that all students "have the intellectual capabilities to understand the material" (p. 354). Anderson further explains that he attributes students' lack of understanding of course concepts to his own or the textbook's failure to communicate the material clearly.

One of the most effective approaches to creating interactive classrooms is to move more of the "class" from the classroom to the laboratory. This approach is particularly important in creating future researchers in the field, as students are socialized into the kind of work they will eventually do as scholars. According to Buncick and Horgan (2001), active learning includes discovery labs, in which students listen to engaging lectures and then respond within the laboratory setting. Within the lab, the goal is to have a "highly collaborative, hands-on, computer-rich, interactive learning environment" (p. 1240). This approach may be especially effective for African American and Latino students, as these students tend to respond better to exercises in which they have to "think things through" rather than shout out solutions (Buncick & Horgan, 2001). When faculty members call on students from different groups to predict results and interpret lab experiments, "everyone can be a star" (p. 1251). Buncick and Horgan conclude that, with this approach, "the sense of competition is diminished, and students who might be less aggressive experience a greater sense of membership in the joint teaching and learning enterprise" (p. 1251).

Instructors may also create interactive classrooms by focusing on student collaboration. Although few STEM programs emphasize student collaboration, researchers have found that learning about study practices from other
students is beneficial, particularly for the amount of time they spend studying (Treisman, 1992). For example, in a study of undergraduate students enrolled in calculus, Treisman (1992) found that African American and Latino students spent between 6 and 8 hours per week studying alone for their calculus class. In contrast, Asian American students studied 14 hours per week, with 8 to 10 of these hours spent alone and 4 to 6 hours spent in a group. Group studying activities included checking one another’s work and learning from one another, as well as eating meals together. In short, the Asian students created a type of “academic fraternity” (Treisman, 1992, p. 366).

Because calculus is a course that typically acts as a gatekeeper for most STEM fields, the absence of collaborative study techniques among African Americans and Latinos may be particularly problematic to the educational attainment of these groups in STEM fields. If faculty and administrators simply describe the potential benefits of collaborative study practices, it may encourage more Blacks and Hispanics to engage in these behaviors. However, faculty and administrators are more likely to encourage these potentially effective behaviors by actively facilitating positive student interactions with peers and faculty, creating and supporting effective study groups, and developing and promoting an atmosphere that encourages students to work together to help one another rather than compete with one another (Treisman, 1992).

Role Models and Mentoring

A final institutional approach to encouraging attainment for Blacks, Hispanics, and American Indians/Alaska Natives in STEM education pertains to role models and mentoring. Over the past decade, several studies have described the lack of faculty mentors for students of color (Armstrong & Thompson, 2003; Cheatham & Phelps, 1995; Davidson & Foster-Johnson, 2001; Ellis, 1997; Robertson & Frier, 1994). At the graduate level, the lack of faculty mentors for students of color is particularly salient because graduate work often requires working closely with faculty members on research projects.

Researchers consistently note that the shortage of Black, Hispanic, and American Indian/Alaska Native faculty in colleges and universities across the country results in insufficient mentoring for students from these groups (Blanchett & Clarke-Yapi, 1999; Hood & Freeman, 1995; Linthicum, 1989). These researchers suggest that students of color are more likely than their White counterparts to experience alienating instances of discrimination and
stereotyping, as well as other attitudes and behaviors that impede their educational success, and are less likely to have a faculty mentor to help them avoid or cope with such experiences (Armstrong & Thompson, 2003; Cheatham & Phelps, 1995; Davidson & Foster-Johnson, 2001; Ellis, 1997; Robertson & Frier, 1994). “Stereotype threat” and such forms of oppression as racism, classism, and sexism also create unique challenges for students of color (Spencer, Steele, & Quinn, 1999; Steele, 1999). Students confronted with discrimination in their educational programs often need someone with whom they can talk regarding these issues (Gasman, Gerstl-Pepin, Anderson-Thompkins, Rasheed, & Hathaway, 2004).

The absence of faculty role models may be especially problematic for female students of color in STEM fields. Female STEM participants, especially Black and Hispanic females, often come from families in which the mother worked outside the home and in which students were urged to develop independence (Hanson & Johnson, 2000). When these women enter college, however, they encounter STEM faculties that are overwhelmingly White and male. As such, many students of color cannot find mentors who share their cultural backgrounds and perspectives (Hanson & Johnson, 2000).

A review of the national data confirms the paucity of faculty of color in many core STEM fields. Comparing the data in Tables 4.1 and 4.2 shows the severe underrepresentation of Blacks and Hispanics among faculty at 4-year colleges and universities relative to their representation among bachelor’s degree recipients, regardless of field. But the underrepresentation is especially high in science and engineering fields. Table 4.2 shows that, among full-time faculty at 4-year colleges and universities in fall 2003, Blacks represented only

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### TABLE 4.2

Distribution of Full-Time Faculty at 4-Year Colleges and Universities by Race/Ethnicity in Selected Fields, Fall 2003

<table>
<thead>
<tr>
<th>Field</th>
<th>Total</th>
<th>Black</th>
<th>Hispanic</th>
<th>Asian</th>
<th>White</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>100.0%</td>
<td>5.1%</td>
<td>3.0%</td>
<td>9.7%</td>
<td>80.3%</td>
<td>2.0%</td>
</tr>
<tr>
<td>Engineering</td>
<td>100.0%</td>
<td>4.9%</td>
<td>2.4%</td>
<td>21.7%</td>
<td>69.3%</td>
<td>1.8%</td>
</tr>
<tr>
<td>Natural sciences</td>
<td>100.0%</td>
<td>3.4%</td>
<td>2.6%</td>
<td>15.7%</td>
<td>77.1%</td>
<td>1.3%</td>
</tr>
<tr>
<td>Business</td>
<td>100.0%</td>
<td>4.3%</td>
<td>1.9%</td>
<td>13.9%</td>
<td>76.9%</td>
<td>3.1%</td>
</tr>
<tr>
<td>Education</td>
<td>100.0%</td>
<td>6.6%</td>
<td>3.3%</td>
<td>4.1%</td>
<td>83.1%</td>
<td>2.9%</td>
</tr>
</tbody>
</table>

4.9% of faculty in engineering and 3.4% of faculty in natural sciences. Similarly, Hispanics represented only 2.4% of faculty in engineering and only 2.6% of faculty in natural sciences (Cataldi et al., 2005).

The importance of mentoring relationships is clear, as higher education research consistently shows positive effects of mentoring on undergraduate persistence and graduate school matriculation (Armstrong & Thompson, 2003; Cheatham & Phelps, 1995; Davidson & Foster-Johnson, 2001; Ellis, 1997; Robertson & Frier, 1994). Finding faculty members who appreciate the perspectives of students of color and who respect and value the contributions of scholars outside the White male canon can have a positive influence on the undergraduate experience and encourage the pursuit of a graduate degree. According to Smith (2000), “It is especially important for black female students to have early and extensive exposure to black women employed in the sciences, both in teaching and in research” (p. 351).

Must mentors be of the same ethnic or racial group as their mentees? Can Black and Hispanic students benefit from mentoring relationships with White professors? Given the grim statistics related to the racial/ethnic composition of faculty in science and engineering fields, majority faculty, in addition to faculty of color, must serve as mentors for Black and Hispanic students, and Black and Hispanic students must seek mentors regardless of the race/ethnicity of faculty. Even at minority-serving institutions, the majority of STEM faculty members are White and Asian (Gasman, Baez, & Turner, 2007).

Promoting student-faculty mentoring relationships at the undergraduate level probably has many benefits. Strong faculty relationships may foster the self-confidence and support that students need to enter and complete future graduate study. Such relationships also provide students of color with opportunities to observe research approaches and skills that they can later emulate in graduate school. Strong mentoring relationships may involve in-depth conversations about graduate school, further acclimating students to the culture of science and engineering education. Finally, through mentorship relationships, faculty may introduce students to their academic and professional networks, networks on which students may later draw during graduate school.

Conclusion

Preparing and encouraging undergraduate students of color to pursue graduate education in the STEM fields is a persisting problem. We know that
students of color are not completing undergraduate degrees in STEM fields and entering and completing graduate degree programs in STEM programs at the same rate as their White and Asian counterparts are. That said, how can we solve the problem? This chapter summarizes four broad approaches that researchers and practitioners recommend: developing integrated support systems, ensuring inclusive curricula, promoting interactive classrooms, and increasing the availability of mentoring.

In addition to pursuing these four approaches, we must develop greater understanding of the educational experiences of graduate students of color in general and graduate students of color in STEM fields in particular. Many questions are currently unanswered. For instance, how does the transition from bachelor's degree programs in STEM to graduate STEM programs vary based on characteristics of the undergraduate and graduate institution? What mechanisms most effectively ease the transition from undergraduate to graduate STEM programs for students of color? Why are students of color leaving the STEM pipeline between the master's and Ph.D.? How do experiences in STEM fields vary among students of color? Addressing these and other questions requires rigorous research using a range of methodologies. Existing research relies primarily on descriptive analyses of students' experiences at single institutions. These descriptive analyses must be supplemented by more sophisticated statistical analyses that control for other explanations for the observed relationships, as well as rigorous qualitative work that probes the experiences of students of color in the STEM fields. Such research is required to understand more completely the most effective strategies for promoting educational attainment of students of color in STEM fields and ensuring that pathways to graduate study for students of color in STEM are accessible. In closing, as researchers and practitioners, we must remember that a society in which scientific knowledge is limited to the few cannot be an enlightened society.

References


Note

1. Steele (1999) argues that stereotype threat, a self-evaluative threat, negatively influences performance by shifting an individual’s focus from performing a particular task to worrying that low performance will confirm a negative stereotype about a group to which the individual belongs.