Factors in K–12 Education That Influence the Success of Racial and Ethnic Minority Students in the STEM Circuit

RESEARCH SHOWS THAT SEVERAL FACTORS in kindergarten through grade 12 hinder or contribute to racial and ethnic minority students' success in the STEM circuit. One central factor that limits their success in the STEM circuit is their inadequate levels of academic preparation for college (Anderson, 1996; Astin and Astin, 1992; Bonous-Hammarth, 2006; Chang, Cerna, Han, and Sàenz, 2008; Denson, Avery, and Schell, 2010; Fenske, Porter, and DuBrock, 2000; Grandy, 1998; Maple and Stage, 1991; Moore, 2006; National Science Foundation, 2006; Seymour and Hewitt, 1997). Moreover, a number of factors in K–12 contribute to racial and ethnic minority students' lack of academic preparedness for college-level work in STEM (Bonous-Hammarth, 2006; Denson, Avery, and Schell, 2010; Grandy, 1998; Hrabowski and Maton, 1995; Lewis, 2003; May and Chubin, 2003; Moore, 2006; Seymour and Hewitt, 1997). Beyond academic preparation, however, several other precollege variables influence racial and ethnic minority students' success in STEM.

This chapter synthesizes factors in K–12 that restrict and promote racial and ethnic minority students' success in the STEM circuit. Specifically, three questions guided this chapter: What factors in K–12 hinder the success of racial and ethnic minority students in the STEM circuit? What factors in K–12 contribute to the success of racial and ethnic minority students in the STEM circuit? What initiatives in K–12 have been implemented to foster the success of racial and ethnic minority students in the STEM circuit?

We synthesize existing research to address each of these questions successively. The first section briefly discusses the critical connection between academic preparedness in K–12 and success in the STEM circuit, the second highlights factors in K–12 contributing to the insufficient academic preparation among racial and ethnic minority students in STEM education, and the third identifies factors in K–12 that contribute to the success of racial and ethnic minority students in the STEM circuit. The final section describes initiatives implemented in K–12 to help increase the success of racial and ethnic minority students in the STEM education circuit.

The Link Between Academic Preparedness in K–12 Education and Minority Students' Success in STEM

A preponderance of research illustrates that success in the STEM circuit is based on adequate academic preparation for college-level work in STEM (Bonous-Hammarth, 2000, 2006; Denson, Avery, and Schell, 2010; Grandy, 1998; Hall and Post-Kammer, 1987; Oakes, 1990; Rendón and Triana, 1989). Specifically, the mathematics and science courses that students take before college determine who will receive further training in STEM fields (Anderson, 1996; Astin and Astin, 1992; Chang, Cerna, Han, and Sàenz, 2008; Denson, Avery, and Schell, 2010; Fenske, Porter, and DuBrock, 2000; Maple and Stage, 1991; Maton, Hrabowski, and Schmitt, 2000; National Science Foundation, 2006). For example, using data from the National Education Longitudinal Study (NELS: 88/00), which sampled more than twelve thousand students in eighth grade and tracked them for twelve years, Adelman (2006) found that the academic intensity of students' high school curriculum was a more powerful predictor of their ability to complete the baccalaureate degree than any other precollege factor.

Despite the salient connection between academic preparation in K–12 and success in the STEM circuit, research shows the enrollment of Blacks, Hispanics, and Native Americans is limited in mathematics and science courses in K–12 (Bonous-Hammarth, 2000, 2006; Hrabowski and Maton, 1995; Maton, Hrabowski, and Schmitt, 2000; Moore, 2006; Seymour and Hewitt, 1997; Rendón and Triana, 1989; Simpson, 2001). Bonous-Hammarth (2000), who examined a nationally representative sample using cross tabulations, factor analyses, and logistic regressions, found that Black, Hispanic, and Native American undergraduates were less likely to be retained in science, mathematics, and engineering majors in college compared with their White and AAPI counterparts because they were inadequately prepared in K–12 to succeed in these subjects. A study of women and racial and ethnic minority students in STEM concluded that "one cannot understand why . . . minorities are underrepresented in science and engineering unless one understands that the related behaviors are formed . . . in the years prior to college. Although collegiate interventions . . . can increase minority students' participation rates, the critical damage is done much earlier" (Leslie, McClure, and Oaxaca, 1998, p. 268).

The next section discusses the variables that hinder racial and ethnic minority students' academic preparedness for college-level work in STEM.

K–12 Contributors to the Insufficient Academic Preparation of Minority Students in STEM

As discussed, research indicates that insufficient academic preparation among minority students in science and mathematics in K–12 education is tightly coupled to their lack of success in the STEM education circuit. Accordingly, this section highlights eight factors in K–12 that contribute to the inadequate academic preparation of racial and ethnic minority students in STEM: (1) school district funding disparities, (2) tracking into remedial courses, (3) underrepresentation in Advanced Placement courses, (4) unqualified teachers, (5) low teacher expectations, (6) stereotype threat, (7) oppositional culture, and (8) premature departure from high school.

School District Funding Disparities

One factor that contributes to the underpreparedness of racial and ethnic minority students in the STEM circuit is disparities in school funding (Adelman, 2006; Flores, 2007; Oakes, 1990). In many cases, schools are funded through local property taxes. Thus, schools in more affluent neighborhoods receive more funding per pupil than schools in less wealthy communities, putting Blacks, Hispanics, and low-income students at a disadvantage because they are more likely to live in inner cities and underresourced communities. For example, data from the National Assessment of Educational Progress (NAEP) show that, although 3 percent of White eighth graders are in schools where more than 75 percent of the students qualify for free or reduced lunch, 35 percent of eighth-grade Blacks and 34 percent of Hispanics are in such schools (Flores, 2007). As a result of this funding system and the fact that many racial and ethnic minorities are more likely to come from less affluent communities, school districts that serve a large number of Blacks and Hispanics receive less local and state funding to educate students compared with school districts that serve a low percentage of racial and ethnic minority students (De La Cruz, 1998; Fergus, 2009; Flores, 2007; Gándara and Contreras, 2009; Rendón and Hope, 1996; Wilkins and Education Trust, 2006). Although we do not have access to these data for Southeast Asian American and Pacific Islander students because they suffer from major economic disparities (U.S. Census Bureau, 2004b, 2004e), we can hypothesize that these groups also disproportionately attend schools that suffer from such funding disparities.

The funding disparity between school districts is tightly coupled with the kind of resources their schools are able to provide for students. For example, schools with more resources are able to offer smaller classes, which positively contribute to students' learning and achievement (Wenglinsky, 1997). This situation puts racial and ethnic minority students at a disadvantage, given that they disproportionately attend schools with fewer resources and therefore larger classes. Moreover, because racial and ethnic minority students attend K–12 schools that receive less funding, these schools typically are not able to provide the latest books, laboratories, instructional material, and technology compared with those that receive more funding (May and Chubin, 2003). According to May and Chubin, the disparity in school funding also engenders a digital divide, further impairing racial and ethnic minority students' ability to succeed in mathematics and science (Rendón and Hope, 1996).

Tracking into Remedial Courses

Another systemic factor that contributes to the disproportionate underpreparedness of racial and ethnic minority students is academic tracking. Academic tracking can be defined as the schools' systematic placement of students in classes based on their performance on standardized testing or teachers' perception of their academic ability (Oakes, Gamoran, and Page, 1992). Such tracking promotes racial and ethnic inequality because students who are placed in high-achieving academic tracks are exposed to more complex and challenging classroom instruction than those who are placed in low-achieving academic tracks. For example, Gamoran, Porter, Smithson, and White (1997) conducted a quantitative study using data from school districts in San Francisco and San Diego, California, and Rochester and Buffalo, New York. The researchers selected these districts because they were urban districts with a high percentage of low-achieving students and had recently implemented new mathematics initiatives. Using a three-level hierarchical model, they found that students in high-achieving academic tracks learned more than students in low-achieving academic tracks. To this end, the authors concluded, "General-track math classes should be eliminated. Instruction is weak, achievement is shallow, and general math is a dead end for students' mathematics careers" (p. 333).

Moreover, existing empirical research shows that Blacks and Hispanics are overrepresented in low-ability or remedial tracks (Bonous-Hammarth, 2006; Oakes, 1990, 1995; Simpson, 2001; Tyson, Lee, Borman, and Hanson, 2007), even when their scores on standardized assessments are equal to or better than those of their White peers (Gándara, 2006; Flores, 2007; Oakes, 1995). Indeed, in a comprehensive review of the literature on women and racial and ethnic minority students in science and mathematics, Oakes (1990) noted that Blacks and Hispanics are tracked into remedial courses in elementary schools, which subsequently makes it difficult for them to succeed in mathematics and science courses as they advance through the education system. Although no information is readily available regarding the tracking of Southeast Asian Americans, Xiong (2010) has argued that those students may be disproportionately channeled into remedial tracks in K–12 schools and that such tracking negatively influences their future choices regarding postsecondary education as well. Because tracking hinders minority students' ability to learn advanced science and mathematics and may negatively influence their college choices, it is an important barrier to educational equity (Tate, 1995b).

Underrepresentation in Advanced Placement Courses

Although racial and ethnic minority students are overrepresented in remedial courses, they are underrepresented in Advanced Placement (AP) courses (May and Chubin, 2003). Indeed, Adelman (2006), using nationally representative data, provided evidence of the disparity in access to AP courses suffered by racial and ethnic minority students. Specifically, he found that, compared with White or AAPI students, Hispanics are far less likely to attend high schools that offer AP courses in subjects such as trigonometry and calculus. Similarly, Ladson-Billings (1997) explains that schools that disproportionately serve a large number of Black students tend to have "less demanding mathematics programs and offer fewer opportunities for students to take such gatekeeper courses as algebra and calculus that lead to increased opportunities at the college level and beyond" (p. 701). This underrepresentation in AP courses is important because college preparatory coursework has a positive impact on a variety of achievement outcomes such as higher scores on standardized college entrance assessments and is tied to more completed years of education (Bonous-Hammarth, 2006; Fergus, 2009). Thus, the underrepresentation of Blacks and Hispanics—and possibly Southeast Asian Americans—in AP courses negatively influences their preparation and subsequent success (Solórzano and Ornelas, 2004; Xiong, 2010).

Even when Advanced Placement courses in mathematics and science are available, many minority students do not engage in them for several reasons (Clewell, Anderson, and Thorpe, 1992). First, racial and ethnic minority students do not view these courses as relevant to their future educational and career trajectories. Second, many minority students view courses in advanced mathematics and science as difficult and do not believe it is worth investing additional time to do well in them. Indeed, although Blacks plan to pursue scientific careers in numbers similar to Whites, because they are not adequately prepared academically, they abandon their pursuit of science careers once they start to encounter more challenging courses (Lewis, 2003). Third, math anxiety can cause racial and ethnic minority students to avoid participating in advanced mathematics and science courses. Finally, perhaps the most critical cause of the underrepresentation of racial and ethnic minority students in AP courses is their elementary and junior high school experiences. That is, because a disproportionate percentage of Blacks and Hispanics have been placed in remedial or general mathematics and science tracks, they are ill prepared to succeed in more rigorous mathematics and science courses in high school and beyond.

Unqualified Teachers

The underrepresentation of qualified teachers among educators who serve large numbers of racial and ethnic minority students is another contributor to their lack of academic preparedness in STEM. A report from the National Science Foundation (2010c) underscores the severity of racial and ethnic minority students' not having equal access to qualified teachers in mathematics and science. For example, the report noted that, in 2004, White fifth graders were 51 percent more likely to be taught by teachers with a master's or advanced degree than their Black and Hispanic peers. Similarly, Flores (2007) and others (for example, Bissell, 2000; Darling-Hammond, 2000; Fergus, 2009; Ladson-Billings, 1997; Tate, 2008) have explained that students attending predominantly Black and Hispanic schools are twice as likely to be taught by teachers with three years of teaching experience or less, compared with those attending predominantly White schools.

Although the overexposure to unqualified teachers is a racial issue, it is also a socioeconomic one. According to Mayer, Mullens, and Moore (2000), the percentage of teachers in high-poverty schools who are inexperienced is 20 percent, compared with 11 percent of those at low-poverty schools. In addition, Flores (2007) noted that, whereas out-of-field teachers teach 19 percent of classes in low-poverty schools, that figure is 34 percent in high-poverty schools. Flores also explains that the least-prepared teachers are disproportionately found in underresourced schools populated by low-income racial and ethnic minority students from inner cities and rural communities. Because a disproportionate number of racial and ethnic minority students are deprived of access to qualified mathematics teachers, which hinders achievement and limits their participation in key aspects of the knowledge-based economy, efforts to provide ways for them to become literate in mathematics is a civil rights issue (Schoenfeld, 2002).

Evidence regarding the impact of teacher preparation on student outcomes is generally consistent in its indication that teacher qualifications in the subject they teach does, in fact, affect success among all students in the STEM education circuit. A majority of existing research on this topic suggests that students who are taught by individuals with a degree in the subject are more likely to have more positive educational outcomes (Goldhaber and Brewer, 1997a, 1997b, 2000; Hill, Rowan, and Ball, 2005; Monk, 1994; Rowan, Chiang, and Miller, 1997). For example, using data from the NELS, Goldhaber and Brewer (2000) used multiple regression techniques to examine the relationship between teacher subject certification and students' academic achievement. Their results revealed that math students who were instructed by teachers with baccalaureate or master's degrees in mathematics had higher test scores compared with students who were taught by teachers with out-of-subject degrees.

Low Teacher Expectations

In addition to unqualified teachers, teachers' low expectations can hinder the achievement of racial and ethnic minority students in math and science courses (Bissell, 2000; Collins, 1992; Fergus, 2009; Oakes, 1990; Thompson, Warren, and Carter, 2004). Moreover, the relationship between teachers' expectations and academic achievement appears to be a reciprocal one. That is, although teachers' expectations influence academic achievement, students' academic performance can also affect teachers' expectations of those pupils. Indeed, teachers may be more likely to develop expectations about and treat their students in a manner that is more consistent with those students' performance on standardized assessments than their actual abilities (Thompson, Warren, and Carter, 2004). Thus, given that racial and ethnic minority students are likely to perform lower on standardized math and science examinations than their majority counterparts (see the first chapter), teachers are more likely to have higher expectations for White than minority students.

In turn, research demonstrates that teachers' expectations can influence academic performance, suggesting that those expectations can become a self-fulfilling prophecy for students. More specifically, mathematics and science courses are viewed as higher-order disciplines, and teachers are inclined to perceive racial and ethnic minority students as lacking ability in those areas and send subtle messages that such disciplines are White male domains (Clewell, Anderson, and Thorpe, 1992). Moreover, such messages can lead to differences in teaching behavior and subsequent achievement (Bissell, 2000). In addition, racial and ethnic minority students in particular seem to be influenced by what they believe teachers think of them and their ability to succeed in mathematics and science courses (Clewell, Anderson, and Thorpe, 1992).

It is important to note that, although existing research shows that teachers' expectations can have a negative impact on the academic success of racial and ethnic minority students in STEM, it also indicates that caring teachers can have a positive impact on the academic preparedness and success of racial and ethnic minority students in those fields (Brown, 2002; Fries-Britt, Younger, and Hall, 2010). For example, using in-depth qualitative interview methods, Brown (2002) examined the experiences of twenty-two Hispanic students majoring in engineering to understand the factors that affected their academic success and found that caring and kind teachers in K–12 played a critical role in their academic achievement in college.

Stereotype Threat

Closely related to negative teacher perceptions and low teacher expectations is the concept of stereotype threat. Stereotype threat has been defined as "a situational threat—a threat in the air—that, in general form, can affect the members of any group about whom a negative stereotype exists. Where bad stereotypes about these groups apply, members of these groups can fear being reduced to that stereotype. And for those who identify with the domain to which the stereotype is relevant, this predicament can be self-threatening" (Steele, 1999, p. 614). Although stereotype threat is often associated with Black students, research has shown that it is applicable to several groups in both K–12 and higher education settings (see, for example, Aronson, Quinn, and Spencer, 1998; Good, Aronson, and Inzlicht, 2003; Spencer, Steele, and Quinn, 1999; Steele and Aronson, 1995). For example, research shows that stereotype threat may account for the academic outcomes of females in mathematic courses (Inzlicht and Ben-Zeev, 2000; Good, Aronson, and Harder, 1999), students from low socioeconomic status (Croizet and Claire, 1998), and any groups for whom stigma has been imposed on their intellectual ability (Aronson and others, 1999). Thus, stereotype threat can be one of the factors implicated for the academic outcomes for minorities in STEM education.

Several studies have developed and tested interventions that may ameliorate the negative effects of stereotype threats (Aronson, Fried, and Good, 2002; Good, Aronson, and Inzlicht, 2003; Wilson and Linville, 1985). Good, Aronson, and Inzlicht, for example, randomly assigned 138 seventh-grade students (63 percent Hispanic, 15 percent Black, and 22 percent White) to four groups that were mentored by college students to determine whether their mentoring intervention would ameliorate the threat of gender stereotypes and reduce the gender gap in mathematics test scores in the sample. The first treatment group learned about the expandable nature of intelligence. The second treatment group learned that everyone encountered difficulty when initially transitioning into seventh grade but that things would improve. In the third treatment group, students learned the combination of the first two messages. These three groups were compared with the fourth, or control, group. At the end of the school year, students completed a statewide standardized test in mathematics and reading. Using analysis of variance tests, Good, Aronson, and Inzlicht discerned that, in all three experimental groups, the gender gap disappeared. Although not specifically focused on racial stereotypes, Good, Aronson, and Inzlicht's intervention (2003) suggests that, although stereotype threat may impede academic progress for racial and ethnic minority students, the effects can be reduced or eliminated with interventions designed to psychologically combat the negative stereotypes. Moreover, these findings are supported by earlier studies (Aronson, Fried, and Good, 2002; Wilson and Linville, 1985). We revisit the impact of stereotype threat later.

One phenomenon related to increased likelihood of stereotype threat is tokenism—being one or one of a few members of an identity group. Indeed, research has found that people are sensitive to being in the minority (Kanter, 1977; Lord and Sàenz, 1985), and being a token can result in increased attention from others and responsibility to represent one's own group (Sàenz, 1994). Scholars have also demonstrated that women who expect to be tokens are more likely to expect to be stereotyped than men (Cohen and Swim, 1995). Although this research focuses on women, we can hypothesize that racial and ethnic minority students in general and in STEM specifically who feel like tokens will feel increased susceptibility to being stereotyped as well, which could make them more vulnerable to stereotype threat.

Oppositional Culture

Researchers have also implicated oppositional culture for the negative academic outcomes of minorities in kindergarten through twelfth grade. Oppositional culture is a theory that Fordham and Ogbu (1986) proposed to explain the academic disengagement of Blacks. The authors explain that Blacks have formed a culture in opposition to mainstream values and norms stemming from the racial oppression, enslavement, and discrimination they have experienced. This oppositional culture acts as a barrier between Blacks and Whites, and it provokes Blacks to persuade their same-race peers to devalue academic success because of its association with "acting White."

Several researchers have raised criticism and concern about oppositional culture as an explanation of the academic disparities faced by Blacks (Ainsworth-Darnell and Downey, 1998; Cook and Ludwig, 1998; Kao and Tienda, 1998; Tyson, Darity, and Castellino, 2005). For example, Cook and Ludwig (1998) argue that Blacks have a desire to attend college, spend an equal amount of time on homework, and have similar rates of absenteeism compared with their White counterparts from the same socioeconomic class. Notwithstanding the criticism, some support does exist for the theory's relevancy in accounting for the disparity in educational outcomes among Blacks (Ford, Grantham, and Whiting, 2008), particularly Black males (Lundy, 2005; Majors and Billson, 1992). Further, using NAEP data collected from students who were fourth graders in 1998, researchers have found that oppositional culture is not limited to Blacks; other racial and ethnic groups experienced oppositional culture as well (Farkas, Lleras, and Maczuga, 2002). For example, the NAEP data revealed that Blacks and Hispanics experienced significantly more oppositional peer culture than Whites. In addition, Native Americans experienced more significant oppositional peer culture than Whites but not to the same degree as Hispanics and Blacks. Although a lot of criticism exists about oppositional culture, this theory could plausibly be used to explain the negative educational outcomes of racial and ethnic minorities in K–12, particularly in STEM education. This literature on oppositional culture highlights the importance of educators and school personnel in K–12 encouraging all students, especially racial and ethnic minority students, to be cognizant of the relationship between peer interaction and academic achievement. We revisit the importance of peers later.

Premature Departure from High School

Finally, premature departure from high school plays a critical role in the inadequate academic preparedness of racial and ethnic minority students in the STEM circuit (Fergus, 2009; Gándara and Contreras, 2009). This situation appears to be particularly salient for Hispanic students who, according to data from Child Trends Databank (2005), exhibit a dropout rate between ages sixteen and twenty-four of 23 percent, while that figure is 11 percent for Blacks and 6 percent for Whites. Given that most careers in STEM require postsecondary training, many Hispanic students miss the chance to even consider a career in STEM because of their departure from the STEM circuit—and the education circuit altogether—in high school (Gándara and Contreras, 2009; Tornatzky, Macias, and Solis, 2006). As we noted in the first chapter, it is also evident that disproportionately large numbers of Southeast Asian Americans and Pacific Islanders also fail to complete high school (Figures 9 and 10).

In summary, research indicates that academic preparedness in K–12 is crucial for the ability of racial and ethnic minorities to be successful in the STEM circuit. Many of those students are insufficiently prepared to succeed in the STEM education circuit, however. To enhance the preparation and success of racial and ethnic minority students in STEM education, it is critical that the factors that negatively affect the success of minority students in K–12 be mitigated. The remaining section of this chapter focuses on variables in K–12 that contribute to the success of racial and ethnic minority students in the STEM circuit.

K–12 Factors That Promote the Success of Minority Students in STEM

Although educational researchers have highlighted the variables in K–12 that hinder the academic preparation of racial and ethnic minority students in STEM, they have also identified six major factors in K–12 that contribute to success among racial and ethnic minority students in the STEM circuit. This section discusses those six variables: (1) parental involvement and support, (2) bilingual education, (3) culturally relevant teaching, (4) early exposure to careers in STEM, (5) interest in STEM subjects, and (6) self-efficacy in STEM domains.

Parental and Support Involvement

A number of researchers have noted that parental expectations and involvement can facilitate the success of racial and ethnic minority students—Black students in particular—in the STEM circuit (Fries-Britt, Younger, and Hall, 2010; Hrabowski, 2003; Hrabowski and Maton, 1995; Russell and Atwater, 2005; Smith and Hausfaus, 1998). Russell and Atwater, for example, interviewed eleven Black college students attending a predominantly White institution (PWI) to gain insight into factors that lead them to pursue and persist in STEM majors. They highlighted the importance of the participants' parents emphasizing the significance of a good education and having high expectations while the students were in primary or secondary schools. Participants also credited their parents for helping them develop good study skills. Similarly, a study that Moore (2006) conducted with forty-two Black males in engineering revealed how the participants' parents affected their desire to pursue engineering in college. Although research underscores the impact of parental expectations and involvement on success among racial and ethnic minority students in STEM in K–12 and higher education, it also shows that parents of Hispanic students may not know how to engage in their children's education (Rendón and Triana, 1989). Therefore, Rendón and Triana recommend that schools provide information to parents of Hispanic students and explain to them why their children are engaged in various mathematics and science courses so they will better understand their children's educational process and how to help them.

Bilingual Education

Researchers have also explained how bilingual instruction in mathematics and science courses can contribute to success among racial and ethnic minority students (for example, AAPI, Hispanic, and Native American) with limited English proficiency in the STEM circuit (see, for example, De La Cruz, 1998; Gándara, 2006; Rendón, 1982; Rendón and Hope, 1996; Rolon, 2003; Rosenthal, 1993). Gándara estimates that at least 50 percent of Hispanic students in California begin school with a language other than English. Consequently, a very large percentage of Hispanic students grapple with understanding English as well as comprehending the curriculum when they enter school. A federally mandated study on student achievement highlighted the importance of language proficiency by underscoring the fact that English learners consistently score lower on achievement tests than other children, even when compared with their counterparts from similar socioeconomic backgrounds (Puma and others, 1997).

Notwithstanding the academic struggles of English learners in school, research indicates that bilingual education facilitates academic success among students with limited English proficiency. According to Rendón and Hope (1996), "Bilingual education . . . [is] considered essential to help students make the successful transition into an English-driven curriculum" (p. 19). Rolon (2003) echoed Rendón and Hope's assertion by discussing how incorporating bilingualism into education positively affects the achievement of Hispanics. In particular, she discussed six high schools in California and Arizona that were successful in enhancing the achievement of Hispanics by including bilingual education in their curriculum.

Culturally Relevant Teaching

In addition to bilingual education, scholars have discussed the role of culturally relevant pedagogy in facilitating the success of racial and ethnic minority students in mathematics and science in K–12 education (Ladson-Billings, 1995b; Lipman, 1995). Ladson-Billings asserted that culturally relevant pedagogical practices must meet three criteria: they must focus on (1) developing students academically, (2) nurturing and supporting students' cultural competence, and (3) developing students' critical competence. Lipman conducted an ethnographic study of three Black teachers and provided a concrete example of culturally relevant pedagogy for Black students. More specifically, the teachers held high expectations for all students and instilled in them that they all had the desire and potential to learn. They also established meaningful commitments and relationships with students' families to help facilitate the students' academic achievement. In addition, the teachers validated the students' non-Eurocentric lives. Finally, they celebrated the richness of the students' language, culture, and experience.

Culturally relevant pedagogy is an important consideration because, when science and math teachers instruct from a Eurocentric point of view, they fail to include an approach that connects curriculum, instruction, and assessment to the experiences, cultures, and traditions of racial and ethnic minority students (Anderson, 1990; Tate, 1994). Such Eurocentric pedagogy, imposing racial inferiority on racial and ethnic minority students, causes those students to view mathematics as a subject that is exclusively for White males and hinders those students' ability to see the applicability of science and mathematics to their own lives. Thus, it is important to consider the role of culturally relevant pedagogy in efforts to serve minority students.

Research illustrates that incorporating culturally relevant pedagogy into science and mathematics instruction has a positive impact on Black students (Denson, Avery, and Schell, 2010; Ladson-Billings, 1995a; Lipman, 1995; Shujaa, 1995; Tate, 1994, 1995a). Denson and colleagues, for example, conducted an in-depth qualitative study of seven Black high school students regarding their perception of engineering and found that using culturally relevant pedagogy in K–12 was important to attracting those students to engineering programs. In addition, Tate (1995a) provided further evidence of the utility of incorporating culturally relevant pedagogy into mathematics instruction by explaining how one teacher had a positive impact on students' interest and success in mathematics by including social issues that Blacks often encounter in education and society into her pedagogical practices.

In addition to the research on the impact of culturally relevant pedagogy on Black students, several scholars have discussed the importance of incorporating culturally specific knowledge into pedagogical practices when teaching other racial and ethnic minority students as well (Barnhardt and Kawagley, 2005; Gutstein, Lipman, Hernandez, and de los Reyes, 1997; Kaomea, 2003; Nelson-Barber and Estrin, 1995; Rendón and Triana, 1989; Rolon, 2003; Sheets, 1995). Nelson-Barber and Estrin, for instance, explain that teachers need to be intentional about using culturally relevant pedagogy when teaching mathematics and science to Native Americans. They suggest that incorporating the unique aspects of Native Americans' culture will increase their rate of academic success in mathematics and science. Rolon argued that adopting culturally sensitive pedagogy into classroom instruction is necessary to enhance the educational efficacy of Hispanic students. In addition, as we discuss in the next chapter, Kiang (1997, 2002) demonstrated that such culturally relevant pedagogy can have a profound positive impact on the experiences and outcomes of Southeast Asian American students. Therefore, although culturally relevant pedagogical practices in K–12 science and mathematics are lacking, the incorporation of such practices could have a positive influence on racial and ethnic minority students' success in the STEM education circuit.

Early Exposure to Careers in STEM

Research also indicates that a relationship exists between early exposure to science and mathematics careers and long-term success in the STEM circuit (Anderson, 1990; Fries-Britt, Younger, and Hall, 2010; Fullilove and Treisman, 1990; Oakes, 1990; Powell, 1990; Seymour and Hewitt, 1997). Indeed, it has been suggested that, when racial and ethnic minority students have greater access to information about careers in STEM and quality career guidance, they are more inclined to develop interests in mathematics and science fields (Seymour and Hewitt, 1997). Thus, such access and guidance might be critical in fostering minority students' interest in STEM.

One way that racial and ethnic minority students can be exposed to STEM careers early is through connecting with role models in those professions (Lewis, 2003; Tornatzky, Macias, and Solis, 2006). Access and exposure to role models is important because visualizing or seeing people who achieve positive outcomes (such as attaining a professional position in the STEM workforce) can raise one's self-efficacy, the belief that he or she too can achieve those outcomes (Bandura, 1977). Several people in the STEM fields have asserted that the availability of role models could be one factor that facilitates the success of minority students in the STEM circuit (see, for example, American Association for the Advancement of Science, 1989).

Although researchers have provided evidence of the significant impact that teachers and counselors can have on minority students' success in STEM (Bissell, 2000; Brown, 2002; Clewell, Anderson, and Thorpe, 1992; Moore, 2006), evidence that highlights the impact of minority role models—that is, individuals who model minority success in STEM professions—is difficult to find. Research does suggest that having parents who are STEM professionals is correlated with success in STEM education (Astin and Astin, 1992; Grandy, 1994), but the actual effects of nonparental role models are uncertain. In addition, although evidence indicates that peers can also function as powerful role models (Murphey, 1995, l996), the influence of peer role models is also a relatively unexplored area of inquiry. In an earlier study, Thompson and Lewis (2005) explained that empirical support for the relationship between role models and student achievement in mathematics is lacking, and our review of literature is consistent with this assessment. We believe this is a critical area for future research in STEM education.

Interest in STEM Subjects

In addition to the connection between early exposure to STEM fields and success in the STEM circuit, research shows that a relationship exists between racial and ethnic minority students' having an interest in mathematics and science in K–12 and their persistence and success in the STEM circuit (Astin and Astin, 1992; Bonous-Hammarth, 2000; Hall and Post-Kammer, 1987; Hilton, Hsia, Solórzano, and Benton, 1989; Hrabowski and Maton, 1995; Oakes, 1990). For example, Hall and Post-Kammer reported that early interest in science is positively related to students' desire to major in science in college. Similarly, Hrabowski and Maton noted that interest in science is one predictor of future academic success in the physical sciences. Furthermore, Moore's qualitative study (2006) of forty-two Black engineering students who attended a PWI found that having a passion for engineering and mathematics in primary and secondary school contributed to their persistence in higher education.

But it should also be noted that, although interest in STEM majors or careers is an important precursor to the success of racial and ethnic minorities in the STEM circuit, a lack of interest in those careers does not appear to be the primary source of the high departure rates of minority students from STEM education (Anderson and Kim, 2006; Cullinane and Leegwater, 2009; Dowd, Malcom, and Bensimon, 2009; Elliott and others, 1996). For example, it has been reported that one-third of first-year Black, Hispanic, and Native American students and 43 percent of their AAPI peers intend to major in science and engineering (May and Chubin, 2003).

Self-Efficacy in STEM

Another conclusion that can be drawn from existing research is that racial and ethnic minority students' self-efficacy in STEM—that is, their confidence in their ability to learn math and science in primary and secondary education—is a salient predictor of success in STEM education (Colbeck, Cabrera, and Terenzini, 2001; Perna and others, 2009). For instance, using data from the 1971 and 1980 Cooperative Institutional Research Program, which contains a wealth of information from students' precollege years, undergraduate and graduate education, and postsecondary employment, Leslie, McClure, and Oaxaca (1998) found that self-efficacy is an important predictor of success in STEM for racial and ethnic minority students. In addition, using the nationally representative NELS (88:00) data, Holt (2006) noted a relationship between racial and ethnic minority high school students' confidence in their ability to do well in mathematics and enrollment in higher-level mathematics courses. Holt further explained that students' confidence in their ability to do well in mathematics was a predictor of persistence in the STEM education circuit.

The impact of racial and ethnic minority students' self-efficacy on their success in STEM is complicated when considering it simultaneously with other factors. According to Seymour and Hewitt (1997), Blacks and Hispanics experience a conflict between overconfidence and poor preparation, which impairs their success in the STEM circuit. More specifically, many racial and ethnic minority students who major in STEM in college come from high schools where they were viewed as academically superior compared with their peers. In these schools, they developed strong confidence but lacked advanced skills that are necessary to achieve their aspirations because of their lack of participation in Advanced Placement classes. As a result, when those students entered college, they were overwhelmed and at greater risk of switching to less intense majors or dropping out of college.

In summary, a number of factors in K–12 education are instrumental in helping facilitate the success of racial and ethnic minority students in STEM. Being aware of these factors could play a critical role in helping educators, researchers, and policymakers enhance success for racial and ethnic minority students in the STEM circuit. The next section of this chapter delineates initiatives in K–12 to enhance the preparedness and success of racial and ethnic minority students in the STEM circuit.

K–12 Initiatives That Contribute to Preparedness and Success Among Minority Students in STEM

A small body of research highlights programs in K–12 that help facilitate the long-term success of racial and ethnic minority students in the STEM circuit. We review this literature in hopes that these programs will provide practitioners with concrete examples of how some educators have created supportive structures that may increase success among racial and ethnic minority students in the STEM education circuit. We focus on three programs: the Preengineering Program at the University of Akron, the Detroit Area Pre-College Engineering Program, and Say YES to a Youngster's Future. We focus on these programs because, unlike most, empirical evidence of these programs' efficacy was available. We also caution readers, however, that the researchers who have examined these programs have often failed to report on the rigor of their methods or pay attention to the aspects of these programs that are ineffective. Thus, the findings reported in this section should be interpreted with caution.

Preengineering Program at the University of Akron

The University of Akron has promulgated an initiative to increase the enrollment and success of first-generation college students (that is, neither parent earned a bachelor's degree) and Blacks, Hispanics, Native Americans, and AAPIs in the STEM circuit (Lam and others, 2005). More specifically, the university has established a summer and after-school preengineering program, which has several goals:

Reinforcing the self-confidence of racial and ethnic minority high school students in the STEM circuit;

Enhancing students' problem-solving abilities;

Increasing students' awareness of careers in STEM;

Using diagnostic testing to identify deficiencies; and

Providing students with opportunities to use computers and become familiar with the use of word processing, spreadsheets, mathematics software, and the Internet.

Approximately forty students in grades 9 through 12 are admitted into the Preengineering Program each year. Participants must meet the following criteria:

Live in Ohio, Pennsylvania, Indiana, or Michigan;

Demonstrate interest or potential in Advanced Placement courses in mathematics or science;

Demonstrate a level of maturity and independence to enable them to live away from home for six weeks;

Meet federal poverty guidelines;

Achieve a grade point average of 2.5;

Attend a conference with parents; and

Engage in an interview with the director of the program.

Students or their families are not financially responsible for participating in the program. The U.S. Department of Education covers all necessary expenses for students. Students who are formally admitted to the program receive a weekly stipend during the summer and a monthly stipend during the year.

For six weeks during the summer, selected students participate in a series of academic classes such as English, mathematics, physics, biology, and a foreign language. Simultaneously, program participants interact with engineering faculty and staff for about an hour and thirty minutes daily. In this summer program, participants work collaboratively with faculty and staff on building projects, laboratory demonstrations, and other structured learning activities. Faculty members also provide students with advice on career planning and mentoring. In addition to collaborative experiences with faculty, students work collectively with each other on projects that include tasks such as designing bridges, building model roller coasters, designing rockets, testing building materials, and designing electronic circuits.

Aside from the summer program, students also participate in a series of career workshops at regional manufacturing companies and research facilities and attend weekly tutoring sessions throughout the school year. These workshops help students become better exposed to careers in the STEM profession.

Furthermore, they provide an opportunity for students to have one-on-one discussions with the engineers. For participants who are out of state, the Internet serves as a conduit through which they can participate. Tutoring occurs in partnership with the College of Engineering at the University of Akron. More specifically, engineering students from the Increasing Diversity in Engineering Academics program and student members of the National Society of Black Engineers volunteer six hours per week and provide mentorship for participants of the preengineering program.

Lam and others (2005) argue that the preengineering program has been tremendously successful. More specifically, they conducted descriptive analyses of data from 1994 through 2004 and found that 100 percent of the program's participants graduated from high school and 94 percent of those students entered college. The authors concluded that "the University of Akron summer integrated and year-round academic programs have increased access and retention of identifiable under-represented students pursuing STEM careers. . . . The pre-engineering curricula actually results in several significant student outcomes such as (1) increase[d] grade point average, (2) less anxiety toward math and science, (3) fostering the can-do attitude, and (4) increasing personal self-esteem" (p. 18). These findings are limited, however, because sufficient details about the methods used to assess the program were not reported and it is therefore difficult to draw definitive conclusions about the effectiveness of the initiative. Moreover, the long-term effects of this program have not been examined.

Detroit Area Pre-College Engineering Program

Another K–12 program that focuses on increasing the enrollment and success of Black, Hispanic, and Native American students in the STEM circuit is the Detroit Area Pre-College Engineering Program (DAPCEP) (Hill, 1990). Implemented with a grant from the Alfred P. Sloan Foundation in 1976, the DAPCEP works in concert with the Detroit Public School System, local universities, major corporations, and businesses to increase the number of middle and high school students interested in pursuing STEM careers in Detroit.

The DAPCEP provides instructional and motivational activities throughout the school year as well as during the summer for racial and ethnic minority students in grades 7 through 12. More specifically, the DAPCEP includes three interrelated components:

The summer skill intensification program, which offers classes in mathematics, science, computer science, and communication in grades 9 through 12;

Saturday enrichment classes, which are held at several area universities and consist of courses in physics, chemistry, laboratory skills, science, technical writing, chemical, civil, electrical, and mechanical engineering, algebra, trigonometry, calculus, and computer science; and

Preengineering classes in science and engineering that are held at public schools in Detroit. Students participate in science fairs, attend field trips, view presentations by technical speakers, research minority engineers and scientists, and participate in research symposiums.

To be accepted into the DAPCEP, students need to have an interest in mathematics and science, have a minimum grade point average of at least a C+, and have a recommendation from a teacher or counselor.

Although no recent data exist on the efficacy of the DAPCEP, in 1990, Hill sent a survey to 3,170 students who participated in the program from 1976 until 1986. Of that number, 584 people returned the survey. The results revealed that 74 percent of DAPCEP alumni who were enrolled in college were majoring in a STEM-related field and an impressive 81 percent of DAPCEP alumni who were college graduates attained a degree in STEM. These statistics, however, are descriptive in nature and do not clarify whether the program had a causal effect on outcomes in STEM.

Say YES to a Youngster's Future

Another program that was implemented to increase the interest and academic success of Blacks and Hispanics in STEM education is Say Yes to a Youngster's Future (Beane, 1990). This program emerged in 1987 with financial support from the Shell Company Foundation and the National Urban Coalition's Schools Project. The Say Yes program has several goals:

Improving the confidence and competencies of teachers in mathematics and science;

Increasing the mathematics and science competencies and interests of minority elementary school students;

Facilitating the involvement of parents and communities in mathematics and science education; and

Increasing the skill level of racial and ethnic minority students in mathematics and science so they will be prepared for advanced mathematics and science work beyond secondary school (Beane, 1990).

The Say Yes program initially started as a two-year pilot program in the District of Columbia but has since been implemented in schools in Houston and New Orleans. Several criteria determine whether schools can participate: enrollment must be at least 75 percent Black and Hispanic, enrollment must include underachieving students based on their scores on standardized tests in mathematics and science, and the school's principal and a team of teachers must be strongly committed to the program. The Say Yes program comprises four critical elements:

School-based teams: Such teams comprise a small group of teachers and the principal. The teams are charged with participating in staff development activities as well as planning and implementing the project at the school.

Staff development: Using test scores and classroom observations, the school district mathematics and science coordinators work closely with the school-based team to identify areas in the elementary school curriculum that need improvement. School-based teams participate in summer programs and in in-service programs during the school year, where they are trained by master secondary teachers in science and mathematics to develop greater competency with the areas in the curriculum identified as weak. Additional training includes Say Yes Family Math, which helps provide the school team with appropriate philosophy and structure for involving parents in informal school-focused mathematics activities.

Saturday family math and science: Although the times that sessions are offered vary across school districts, they are typically held once a month during the school year. Some sessions are held at the school and others take place at community-based facilities such as zoos, museums, and nature centers and last from two to three hours. Topics include explorations of electricity, chemistry, simple machines, light, weather, flight, fossils, insects, animal behavior, plants, and astronomy. Families work in concert with teachers and students, using activity sheets and instructional material. Spanish translations of the instructional forms are provided for Hispanic families with limited English proficiency. Families also leave the session with activities to try at home with the proper instructional materials needed to do so.

Outreach: To build community support for science and mathematics education, the Say Yes program employs a variety of approaches (for example, conferences, active distribution of information about the Saturday family math and science program, and T-shirts). Efforts to build community support and raise awareness include the schools, representatives from the business sector, political leaders, parents, and community-based organizations.

Research indicates that the Say Yes program has had a positive impact on students' academic performance in mathematics and science (Beane, 1990). More specifically, data from students who took the Metropolitan Achievement Test (MAT) in spring 1987 as a pretest and spring 1988 as a posttest, with classrooms of teachers participating in Say Yes and those who did not compared and students participating in the Saturday Program and those who did not compared, revealed the following results:

The students of teachers participating in Say Yes gained 28.95 points in mathematics, which is equivalent to a 1.2-grade increase among participants, compared with an 18.56-point gain among students in the control classrooms (Beane, 1990).

In reading, the students of teachers participating in Say Yes gained 28.52 points (a 0.7-grade equivalent), while students in the control classrooms gained 15.97 points (a 0.4-grade equivalent). Furthermore, students participating in the Saturday Math Program scored higher on the MAT test

> in mathematics and reading compared with the control group. Specifically, participants gained 25.97 points in mathematics on the MAT, whereas nonparticipants gained 15.65 points, equivalent to a 1.1-grade increase for participants versus a 0.7-grade increase for nonparticipants. Participating students also gained 25.00 points (a 0.5-grade equivalent gain) in reading on the MAT, while nonparticipants gained 12.24 points (a 0.4-grade equivalent gain) (Beane, 1990).

It is unclear whether the evaluators of this program used an experimental or quasi-experimental design in conducting their analyses. Although this evidence supports the efficacy of three programs, this literature is sparse and much remains to be learned about whether such STEM initiatives in K–12 education positively affect minority student outcomes in the STEM circuit.

In sum, existing evidence indicates that STEM-specific programs in K–12 can positively affect racial and ethnic minority student outcomes in STEM. That evidence is not strong, however, and definitive conclusions about the impact of precollege STEM-specific initiatives on minority students' success in STEM should await more inferential studies that can support causal connections. Moreover, extant literature does not critically analyze and identify the extent to which various components of STEM-specific precollege programs influence the outcomes of racial and ethnic minority students, either positively or negatively.

Conclusion

In sum, empirical research demonstrates a relationship between academic preparedness in K–12 and success in the STEM circuit. Notwithstanding, racial and ethnic minority students are least likely to be academically prepared in K–12 to be successful in the STEM circuit. This chapter identified factors in K–12 that contribute to the lack of academic preparedness among racial and ethnic minority students. Furthermore, it delineated factors in K–12 that facilitate the success of racial and ethnic minority students in the STEM circuit. And it focused on initiatives in K–12 to enhance the success of racial and ethnic minority students in the STEM education circuit.

This chapter illustrates the critical relationship between preparedness in K–12 and success in the STEM circuit and indicates that many racial and ethnic minority students are not adequately prepared in K–12 to be successful in the STEM circuit. Thus stronger emphasis must be placed on effectively preparing minority students in K–12 to be successful in the STEM circuit. One way to improve the success of these students is identifying ways to effectively deal with factors that contribute to their lack of academic preparedness in K–12, which are inextricably linked to their ability to succeed in the STEM circuit. Focusing on the success factors and expanding STEM programs identified in this chapter provide useful ways to constructively increase the preparedness and success of minority students in STEM.