

Effective Strategies to Increase Diversity in STEM Fields: A Review of the Research Literature

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This literature review presents the research evidence that exists for ten intervention strategies commonly adopted by programmatic efforts striving to increase diversity in science, technology, engineering, and mathematics (STEM) fields. Also presented is empirical support for three model intervention programs: The Meyerhoff Program, Minority Engineering Program (MEP), and the Mathematics Workshop. The article concludes with a discussion of recommendations for future action and research in this area.

INTRODUCTION

Since 1983, more than 500 reports have been published addressing the problems of science and mathematics education (Laws, 1999). These reports are so similar in their calls for reform that they can be easily summarized as including the following principles:

learn science and mathematics actively by doing them in collaboration with peers and instructors; engage in extended research projects with faculty mentors; explore fewer topics in more depth; achieve scientific literacy by being able to ask and answer questions such as 'How do we know . . .?' and 'What is the evidence for . . .?'; relate scientific and mathematical understandings to contemporary social issues; and develop written and oral communication skills. (Laws, 1999, pp. 218-219)

The bases of the reports suggest that there is much agreement on what should be done to improve science and mathematics education. But it is dangerous to assume that what is recommended for the general STEM student body is necessarily what works best for those who are underrepresented in that population.

To avoid impending shortfalls of scientists and engineers, the U.S. needs to shore up its native talents by increasing the recruitment and retention of those who continue to be underrepresented in science, technology, engineering and mathematics—women, as well as, underrepresented minorities. While some of the same barriers are faced by both women and underrepresented minorities, there are also notable differences. Therefore, these two underrepresented groups have received considerable research attention of their own (see Clewell & Campbell, 2002 for a review that addresses White women and minority women's progress in STEM). As the fastest growing portion of the school-age population, minority students represent a great potential pool of future entrants into STEM fields. In comparison to their White peers, underrepresented minority freshmen are just as likely if not more likely to enroll in science and engineering studies (Anderson & Kim, 2006; Elliott, Strenta, Adair, Matier, & Scott, 1996; U. S. Department of Education, 2000). However, underrepresented minorities are more likely to switch to non-science majors and are less likely to complete a science, mathematics, and engineering degree (Chubin & Babco, 2003; Culotta, 1992; Elliott et al., 1996; Georges, 1999; Morrison & Williams, 1993; U.S. Department of Education, 2000). While approximately one-third of the school-age population consists of African American, Latino, and Native American students, these minority groups currently comprise only 11% of those in STEM occupations (Chubin, May, & Babco, 2005).

The disproportionately low participation of African Americans, Native Americans, and Latinos in STEM fields is attributable to a number of factors, including barriers that are of a

cultural (social expectations for different groups), structural (historical laws and regulations that barred the entry of minorities into education and employment), and institutional nature (discriminatory policies and practices). While societal transformations have reduced formal and legally sanctioned barriers, the lineage of accumulated deficit opportunities within a socially stratified society continues to exert its negative impact. For instance, student achievement in STEM is enhanced by educational advantages such as a rigorous mathematics and science high school curriculum, teachers with superior mathematics knowledge, access to equipment, and lab activities work (Campbell, Jolly, Hoey, & Perlman, 2002). However, educational access and quality continue to be related to socioeconomic status (SES) and racial status (May & Chubin, 2003).

Adelman's national study (2006) found academic intensity of one's high school curriculum to be the most important pre-collegiate factor in providing momentum toward completing a bachelor's degree. Benbow and Arjmand (1990) pointed out that

differences in school programs appear to have a profound effect on levels of ability and achievement, even among the intellectually talented . . . Intellectually talented students will not achieve as highly if not provided with appropriate educational opportunities. (p. 437)

In their national study, Astin and Astin (1992) found that the strongest and most consistent predictor of changes in college students' interest in a science major and career is students' entry level of mathematical and academic competency. However, for example, when compared to White or Asian students, Latino students are far less apt to attend high schools offering trigonometry, much less, calculus (Adelman, 2006). In addition, when compared with students in the highest SES quintile, students in the lowest SES quintile attend high schools that are less likely to offer any mathematics above Algebra II (Adelman, 2006).

To redress the race/ethnic disparity in STEM participation, a range of intervention programs have been created to operate on college and university campuses. These programs typically entail a variety of services and activities designed to address factors affecting underrepresented minority students' interest, motivation, and skills in STEM. The availability of academic and psychosocial support services is critical in light of the finding that what seems to distinguish those who persist from those who transfer out of STEM has less to do with ability, and more to do with the manner in which students respond to the barriers that they encountered. Interviewing a large number of undergraduates who persisted and those who switched out of mathematics, science, and engineering majors, Seymour and Hewitt (1997) found the two groups to be similar in ability and character, but that "nonswitchers were more likely to make effective use of situational resources, to employ a variety of other strategies, and to find ways to tolerate or surmount the same types of difficulties reported by switchers" (p. 232).

Is there research evidence to support the efficacy of commonly adopted intervention strategies? This review was undertaken to examine the scholarly literature for empirical evidence of the effectiveness of an array of strategies that are frequently used in efforts to increase minority participation in STEM fields. The synthesis of existing research findings on intervention approaches can yield valuable insight for informed policy making, future initiatives, and local implementation. While much of the research presented here examines specific effects on underrepresented minority groups, in many cases the effects may be comparable for non-minority students. Conversely, while research on some strategies failed to examine particular effects on minority students, it is quite possible that benefits found for the overall group can also be found for minority group members.

The publications included in this review were identified by conducting searches on education-related databases and search engines, such as Social Science Abstracts, ERIC, Education Abstracts, EBSCOhost, JSTOR, and ProQuest. Searches were conducted using key words pertaining to minorities, higher education, intervention, science, engineering, and retention. Furthermore, in an attempt to identify additional publications for inclusion in this review, citations appearing in relevant retrieved articles were also considered.

It is worth noting that this article's focus on approaches being employed at the higher education setting ought not to be interpreted as suggesting that schools rather than family, government, or business and industry should be held primarily responsible for increasing the participation of underrepresented minorities in STEM. Each of these groups has a stake and responsibility in this endeavor, as well as, the power to exert a positive change. If the future STEM workforce is to substantially increase its current ranks, it must foster and then nurture early children's interest in STEM. This can best be accomplished through collaboration among family, schools, government, and business and industry. Undoubtedly, these groups working together synergistically can accomplish more collectively than as separate entities.

In presenting a review of the research literature, this article begins by examining findings on ten common strategies for which there is considerable research. This is followed by a discussion of the benefits of adopting an integrated intervention approach in which multiple strategies are pursued. In support of this argument, three notable intervention programs and evidence of their effectiveness are presented. Finally, this review concludes with recommended actions and research steps toward strengthening national capabilities through expanding diversity in the STEM pool.

MAJOR INTERVENTION STRATEGIES

Summer Bridge

Pre-college summer bridge programs or transitional programs for low-income and minority students have become "an established part of the effort to recruit, retain, and graduate a population of students underrepresented in higher education" (Ackermann, 1991, p. 201). In a study of 20 prototypical programs to promote the high achievement of underrepresented minority college students, Gándara (1999) noted that the majority of these programs are focused on the sciences, mathematics, and engineering, and additionally, nearly half of these programs include a pre-freshman bridge approach. Although bridge programs vary, they typically entail intensive academic enrichment and other strategies designed to facilitate students' transition and adjustment to college life. Attention to the juncture from high school to college is imperative given the high degree of student attrition that occurs between freshmen and sophomore year (Tinto, 1987). Supplemental instruction through pre-freshman bridge can effectively narrow a preparation gap that is often caused by attendance of impoverished schools with inadequate instruction, poor facilities and equipment, and few positive role models. Minorities tend to be less prepared for a rigorous academic program in college because they are much less likely than Whites or Asian Americans to pursue a rigorous academic course of study or to take advanced placement (AP) mathematics and science courses during high school (Wilson, 2000). A 1990 study by the Rand Corporation found that schools with high minority enrollments generally offer students fewer challenging courses in mathematics and science (Culotta, 1992). Moreover, the higher the SAT mathematics score, the more likely that person will major in science. Investigating the role of ethnicity in science persistence, Elliott and colleagues (1996) found that preadmission variables accounted for a significant amount of the variance of science persistence while ethnicity did not.

While research on the effects of summer bridge program participation is limited, the findings are generally consistent in suggesting that program participants, in comparison to non-participants, are more apt to achieve positive outcome such as persistence into their second college year (Pascarella & Terenzini, 2005). In trying to improve minority student admissions and retention, the four-week bridge program at Georgia State University offers participants (African American developmental studies students) classes in mathematics, reading, composition, study skills, and word processing. Additionally, it provides free tutoring, academic and career counseling, mentoring, and other follow-up services during the academic year. Program evaluation results show high ratings of program effectiveness by students as well as faculty members. Moreover, participants have achieved "a remarkably high retention rate" that exceeds that of all developmental studies students of other races and which matches that of African American students who do not require developmental courses (Gold, Deming, & Stone, 1992). Study

findings of one community college's six-week summer bridge program for minority students, offering academic enrichment and training in "college survival skills," indicated that program participants, in comparison to non-participants, had lower grade point averages, but achieved at comparable or higher levels on academic skills tests, first-year retention, and graduation rates (Evans, 1999). An evaluation of the summer bridge program of the California State University System, a four- to six-week on-campus residential experience that focuses on improving basic skills and familiarizing new students with the university experience, found an increase in freshmen and sophomore retention rates. Moreover, participants were more likely to use campus services, meet more frequently with faculty outside of class, join study groups, and be satisfied with their college friendships (Garcia, 1991). An evaluation of a summer program for incoming freshmen and transfer students at the University of California, Los Angeles found a modest increase in the college persistence rate of participants (Ackermann, 1991).

Summer orientation is recognized as a common component of successful minority programs (Torres, 2000). Data collected from directors of programs that aim to recruit and retain underrepresented students in science and engineering showed that overnight, residential, and summer programs were most frequently cited as being most integral to program success (Matyas, 1991a). Moreover, research on the Meyerhoff Program and the Minority Engineering Program (MEP), two highly regarded intervention programs; have also identified Summer Bridge to be an important factor in their effectiveness (Maton, Hrabowski, & Schmitt, 2000; Morrison & Williams, 1993). In a retention research study conducted by the National Action Council for Minorities in Engineering (NACME), in which data were analyzed for 51 projects, a positive relationship was found between successful minority engineering student retention and the offering of a summer pre-freshman program (Penick & Morning, 1983).

Mentoring

Mentoring programs have become prevalent, and appear to be a widely utilized approach in intervention programs for minorities. In designing intervention programs to increase interest and sustain persistence in STEM fields, Ginorio and Grignon (2000) recommended the consideration of the principle "each student needs at least one person to serve as a mentor, someone who has faith in them and will provide necessary information or support at key junctures involving choice" (p. 167). Despite the growing popularity of mentoring, research evidence on its effectiveness continues to be primarily anecdotal and qualitative since there are few studies attempting to measure effects through the use of a control group that has not been mentored (see Romero's study as cited in Gándara, 1999). According to Gándara, researching the effects of mentoring poses a special challenge because mentoring relationships can vary greatly; a program may show greater within group differences than between group differences (Gándara, 1999).

On the whole, the existing research evidence seems to support the importance of mentoring in undergraduate education (Jacobi, 1991). Frequency of student-mentor contact has been found to positively correlate with students' college adjustment and perceived mentor supportiveness (Santos & Reigadas, 2002). Minority students have reported on the critical role that mentors play in their adjustment to college, and progress toward graduate studies and a career (Freeman, 1999; Lee, 1999). Minority students who participated in mentoring programs have demonstrated such positive outcomes as higher grade point averages, lower attrition, increased self-efficacy, and better-defined academic goals (Santos & Reigadas, 2002; Schwitzer & Thomas, 1998; Thile & Matt, 1995). Mentoring is said to address several causes of college attrition and delayed graduation by facilitating aspects of students' academic and social integration (Redmond, 1990).

The literature on mentoring recognizes a critical distinction between formal or planned mentoring, and informal or natural mentoring. Research suggests that naturally forming relationships are more likely to be successful and result in superior outcomes (Davidson & Foster-Johnson, 2001; Gándara, 1999). Some intervention programs attempt to foster informal mentoring relationships through cohort or community building among peers and program staff. Unfortunately, without intervening circumstances, mentoring appears to be relatively uncommon

at the postsecondary education level, and this appears to be especially true for minority students (Blackwell, 1987; Jacobi, 1991). A longitudinal study involving minority high school valedictorians and salutatorians indicated how without proper role models and supporters to guide them through college, promising students could easily fail to live up to their potential (Arnold, 1993). Arnold observed that

ignored by faculty and outside the central college academic and social structures, the valedictorians at predominantly White institutions never had the opportunity to develop the subtle skills of translating intrinsic academic interests into clearly formulated career goals and effectively managed educational and professional activities. (pp. 277-278)

Jacobi (1991) pointed out that while minority and female students may feel a greater need for mentors, they are more likely to encounter obstacles in obtaining mentoring because of the shortage of female and minority faculty members. This shortage is especially acute in science and engineering. There is some evidence to suggest that minority undergraduates attain more positive attitudes toward research (Frierson, Hargrove, & Lewis, 1994) and the pursuit of graduate studies (see Martinez's study as cited in Gándara, 1999) when they are mentored by female faculty or faculty of color. However, race or gender consistency between mentor and protégé may not be as important as some other factors in the mentoring relationship (Clewell & Ginorio, 1996). Examining student views about race in the mentoring relationship, Lee (1999) found that African American students attending a predominantly White college felt that having an African American faculty mentor was less important than having a mentor in their career field. In their review of mentoring graduate researchers of color, Davidson and Foster-Johnson (2001) argued that knowledge is the key to successful cross-race mentoring: mentors need to have an understanding of their own personal prejudices and attitudes toward race; their protégés' racial maturity, career and professional goals, and strengths; and their organization's diversity efforts, discrimination policies, and professional and social networks.

The critical role that mentoring plays in the educational progress of underrepresented minority students is clearly substantiated in a study by Solórzano (1993) in which he interviewed 66 Chicano/a Ford Foundation Minority Fellowship recipients about their educational experiences. The single-most important factor identified in students' degree attainment was a positive mentoring experience. In a study of non-persistence decisions among Native American undergraduates, Gloria and Kurpius (2001) found that having a socially supportive network is central to academic persistence; particularly strong is the effect of having faculty/staff mentors.

Because of the very limited availability of Chicano/a faculty role models and mentors on college campuses, students more frequently reported receiving mentoring from peers. In a study on the mentoring experiences of Mexican American undergraduates at one institution, Romero (1996) found that these students were most likely to be mentored by a family member (54.4%), followed by a peer/roommate (16.3%), and university personnel (13.6%). A study by Rice and Brown (1990) showed that while some students may prefer a peer mentor over a faculty mentor, peer mentors may not be adequately equipped to provide all the mentoring services that students may desire. Therefore, it is likely that a combination of both faculty and peer mentors can best fulfill the needs of those students seeking mentorship. Mentorship from industry professionals can also be very helpful to STEM students. MentorNet (<http://mentornet.net/>) is a large-scale electronic mentoring program that matches female STEM students as well as underrepresented minority STEM students to professionals in industry and academia for year-long mentoring relationships. E-mentoring is said to allow for flexibility in scheduling and to overcome geographical barriers that may otherwise deter mentoring opportunities. Project results validate the usefulness of the electronic format for mentoring (see Bennett et al.'s study as cited in Kasprisin, Single, Single, & Muller, 2003; Single, Muller, Cunningham, & Single, 2000).

Research Experience

There is considerable evidence from multiple research studies to suggest that engaging in hands-on research, whether within an academic setting or off-campus in a position with industry, is an

effective strategy in increasing the number who pursue degrees and careers in STEM fields. A recent study found that alumni who participated in their university's long-established Undergraduate Research Program reported significantly greater overall satisfaction with their undergraduate education and were more likely to attend and complete graduate school than comparable alumni who had no research experience (Bauer & Bennett, 2003). Using a national sample of students, Pascarella and Staver (1985) controlled for differences in family background, aptitude, secondary school experiences, pre-college career choice, academic major, and college achievement, and found that on-campus employment in science exerted a positive effect on post-sophomore year science career choice.

Hackett, Croissant, and Schneider (1992) found that controlling for social background and academic experiences; undergraduate research and cooperative education programs (paid industry internships) strongly influenced participating engineering students' skills, job values, and life objectives. Those who participated in an industry internship position reported this work experience to be very influential to their career choice, far more so than their classroom experience. Post internship data collected from NACME scholars who participated in the Corporate Scholars Program found that mentoring matters. Successful mentoring either by individuals formally assigned the role or by supervisors, who informally carried out the duties of mentors, resulted in substantial increased interest by interns to return to their host companies and more favorable evaluation of workplace experiences (Highsmith, Denes, & Pierre, 1998). In a survey study of computing majors who were completing an internship, Schambach and Kephart (1997) found students generally expressed a very favorable response to the experience, and reported perceived benefits that included "recruitment advantages, an excellent method of learning, better understanding of organizations and career focus, as well as reinforcement of course learned skills and enhanced confidence in their own professional capabilities" (p. 214). In a study on science persistence among high-ability minority students, those who persisted tended to report that scientists and engineers they knew, knew about, or met in summer jobs or part-time work, especially minority scientists and engineers, influenced them to a greater degree than did parents, friends, and teachers although these individuals were important (Hilton, Hsia, Solórzano, & Benton, 1989).

In Solórzano's (1993) study of Ford Foundation Minority Fellows, many students, especially those in the sciences, reported that engaging in hands-on research experience with faculty was one of their most important academic experiences and was particularly influential to their finishing college and attending graduate school. A program on undergraduate student-faculty research partnership at the University of Michigan, which targets underrepresented minority and female students interested in science, has produced positive effects on retention. Using an experimental design in which student applicants to the program were randomly assigned to either the control or experimental group, the researchers found that program participation positively affected retention for each of the race/ethnic groups examined (Hispanic, African American, and White). Particularly strong effects were found for the lower-achieving African American group (Nagda, Gregerman, Jonides, von Hippel, & Lerner, 1998).

A 1990 study by the National Science Foundation (NSF) showed that participants of NSF's Research Experiences for Undergraduates Program demonstrated a heightened interest in science and engineering, pursuing a graduate degree, and attending graduate school immediately following college completion. While participants chose to be involved with the program for various reasons, underrepresented students (African Americans, Native Americans, Alaskan Natives, and females) were more likely than others to be motivated by wanting to know if science, engineering, or research was appropriate for them. Participation in a summer science research program can also enhance students' social integration. In a study involving past participants of one such program, minority students tended to stress the importance of positive relationships with peers and faculty and how this impacted their decision to continue on to graduate school (Walters, 1997).

Involvement with faculty research at the undergraduate level can help clarify educational and career plans, and enhance students' sense of self-efficacy. Proactive steps to heighten students' self-efficacy are recommended in efforts to expand diversity in science and engineering (Hackett,

Croissant, & Schneider, 1992). Beyond the effects of academic ability and achievement, self-efficacy has been found to be predictive of grades and persistence in technical/scientific majors, as well as perceived career options in a range of science and engineering fields (Lent, Brown, & Larkin, 1986). Research with faculty may entail such professional development experiences as conference attendance, presentation of one's work, and publication submissions—all of which socializes one to a career in research while strengthening self-efficacy. Surveying students engaged in undergraduate research, one study found that a high percentage of students would recommend the experience to others, and that students perceived the most valued skills derived from the experience to be technical skills, problem-solving skills, and the development of professional self-confidence (Mabrouk & Peters, 2000). Similarly, in a qualitative study of students involved undergraduate research at four schools found a high level of satisfaction among participants and the most often cited gains to pertain to increased confidence to "work as a scientist" (Seymour, Hunter, Laursen, & Deantoni, 2004). In an interesting experimental study on mathematics/science self-efficacy enhancing interventions, undergraduates with at least a moderate level of mathematics ability and who were undecided about career plans were randomly assigned to one of four treatment conditions. Four weeks after treatment, those who underwent the performance accomplishment treatment (successful completion of a number series task), continued to show higher levels in mathematics/science course self-efficacy, mathematics- and science-related career interests, mathematics/science relatedness in courses they planned to enroll in the next quarter, and mathematics/science relatedness of their choice of major (Luzzo, Hasper, Albert, Bibby, & Martinelli, 1999).

Undergraduate participation in research also entails the added benefits of informal mentorship through close contact with faculty. Interactions with faculty that combine students' classroom and non-classroom experiences have been found particularly important to student retention (Pascarella & Terenzini, 1991). For both minority and non-minority groups a positive relationship has been found between students' self-reported progress in mathematics and science, and students' satisfaction with student-faculty relations (Eimers, 2000). Analyzing data collected from a national sample of undergraduates and faculty, Drew (1996) found that faculty orientation toward working with students is very strongly related to students' satisfaction with their college science experiences (this measure had a greater effect than all other background and college environmental variables in the regression). Unfortunately, the level of student satisfaction with science faculty relations appears low. In a study involving African American upper division students at 11 public research universities, more students viewed faculty members as discouraging rather than supportive (Blockus, 2001). Aside from building students' knowledge and skills, research work with faculty can be beneficial by providing students with an opportunity to interact meaningfully with faculty outside of the classroom and to develop a basis for a true mentor-protégé relationship.

Paid research work also has the added benefit of helping students defray college expenses. This is especially salient in the case of minority students, who are more apt to face unmet need after financial aid assistance and thus may be more likely to seek employment during college (Long & Riley, 2007). Hispanic students, for example, are more likely to leave college to support family (see Celis's study as cited in Nagda, Gregerman, Jonides, von Hippel, & Lerner, 1998). Meanwhile, Native American science and engineering majors have been found to average more hours of paid work than their peers (Grandy, 1994). While a job that is unrelated to students' academic program can detract time from study and academic pursuits, a job that is related can complement and enrich students' studies through experiential learning. National data reveal that bachelor's degree attainment, along with a host of other positive outcomes, is positively associated with holding a part-time job on campus, but negatively associated with holding a part-time job off campus (Astin, 1993). In another study involving a national sample of college students, working off-campus was found to have a significant negative effect on persistence for minorities (reducing the chance of persisting by 36%) but not for non-minorities (Nora, Cabrera, Hagedorn, & Pascarella, 1996). Quality work experience can socialize students to professional norms and may

result in long-term professional advantages. In their review of the research in this area, Pascarella and Terenzini (1991) concluded that most of the evidence suggests that working during college, particularly in a job related to one's major or initial career aspirations, has a positive net impact on career choice, career attainment, and level of professional responsibility attained early in one's career.

Tutoring

Tutoring has been a long-standing aid in student learning, and is widely used today as an intervention measure to enhance student performance and persistence. College-level tutoring programs can vary greatly in approach, substance, and degree of structure. Those in the tutor role are often upper division students, staff members, or faculty members. Most studies that compare achievement outcomes of students tutored by either peers or staff members have found no differences (Moust & Schmidt, 1994). In his review of peer tutoring, Topping (1996) noted that tutoring is being widely used in varying forms at several hundred institutions, and that student subjective feedback is generally very positive.

In a study involving academically under-prepared college freshmen, length of exposure to tutoring had a consistent effect on course credits earned (House & Wohlt, 1990). In an early study on tutoring by Carman (1975), students enrolled in a remedial course were randomly divided into one of three groups (one group receiving no tutoring, and two groups receiving varying levels of tutoring). Study results indicated that course grade and overall GPA did not differ among the three groups. However, course withdrawal was significantly lower for the tutored groups than the non-tutored group. Moreover, interview results revealed that members of the tutored groups held more positive views about mathematics and other courses. This pattern of increased persistence and positive attitude continued during the two years following the tutoring experience. In a study by Gahan-Rech, Stephens, and Buchalter (1989), positive effects of tutoring were found for mathematics students. Controlling for students' initial mathematics ability, no difference in mathematics performance was found between the group that received no tutoring and the group that attended five or fewer tutoring sessions. The group of students who attended six or more tutoring sessions, however, performed better than the other two groups despite the superior initial mathematics ability of the non-tutored group.

Benefits of tutoring have been demonstrated for not only those receiving the tutoring, but also for those performing the tutoring. In some cases tutors were found to experience greater achievement gains than those who are tutored (Bargh & Schul, 1980). In one study using survey data collected from non-traditional college students at multiple institutions, the strongest predictor of understanding science was teaching science (Lundberg, 2003). Evidence of affective and academic benefits were found for advanced student mentors involved in a minority engineering program in which they interacted with mentees regularly through tutoring and involvement in problem-solving workshops (Good, Halpin, & Halpin, 1998). In an experimental study on the cognitive benefits of teaching, Bargh and Schul (1980) compared performance between a group of undergraduates who studied verbal material to learn for themselves (the control group) and another group who studied the same material to teach it to another person. The group that was preparing to teach scored significantly higher than the control group on a subsequent retention test of the material. In another study in which students were randomly assigned to one of two groups, Benware and Deci (1984) investigated whether students who learned with an active orientation (learning material that they expected to teach another student) would perform better than those who learned with a passive orientation (learning the same material and expecting to be tested on it). Results revealed that the two groups scored equally on rote learning, but the group that learned expecting to teach scored higher on conceptual learning. Similar results emerged from a study by Annis (as cited in Topping, 1996) in which students were randomly assigned to one of three groups. The group that showed the greatest gain on test score was the group that read and taught, followed by the group that read and expected to teach (but who actually did not carry out the task),

followed by the group which read to study only. Therefore, the implication here is that the act of teaching facilitates or reinforces the learning process.

Career Counseling and Awareness

There is much research to suggest a strong connection between career development and student background, particularly with regard to SES (Hill, Pettus, & Hedin, 1990; Mestre & Robinson, 1983). For example, those majoring in natural science tended to be from a higher SES than those pursuing a social science or non-science major (Clark, 1986). Scientists come disproportionately from well-educated families, with fathers engaged in professional or managerial occupations (Pearson, 1986). In a study of undergraduate science and engineering majors conducted by Grandy (1994), a greater proportion of White students than minority students had parents employed in technical, mechanical, and scientific positions. In their national study, Astin and Astin (1992) found that having a father who is an engineer predicts persistence in engineering. In another study Hispanic science and engineering students were found to have received less career counseling from high school teachers and counselors, owned fewer technical toys, and had lower family income levels than their non-minority peers (Mestre & Robinson, 1983). Given the historical under-representation of minorities in higher education, and in prestigious and lucrative careers in mathematics- and science-based fields, career counseling and career awareness have become common intervening strategies used in efforts to recruit and retain minorities in STEM. In a study involving African American and Latino high school valedictorians and salutatorians, Arnold (1993) noted that even with this select group of academic achievers there appeared to be a "critical lack of tacit knowledge about higher education and careers" (p. 277). Moreover, research suggests that in comparison to their White peers, minority students tend to demonstrate a lower career decision-making self-efficacy (Gloria & Hird, 1999), and perceived greater ethnic identity barriers in their career development (Luzzo, 1993).

In a study involving middle and high school students, and students from an historically Black college or university (HBCU), personal contact with a scientist was identified as the major factor affecting students' science-related career decisions. Students who personally knew a scientist, mathematician, or engineer scored a higher mean than did those lacking this type of acquaintance on such variables as participation in science-related hobbies and activities, academic self-image, science-related career interest, parental encouragement and support, perceived relevance of mathematics and science, and ability in mathematics and science (Hill, Pettus, & Hedin, 1990). A study of African American engineering students found that prior knowledge of the profession and opportunities to talk with engineers was a factor that differentiated between those who remained in the major and those who switched (Good, Halpin, & Halpin, 2002). Another researcher found that positive images of scientists and engineers is positively related to students' commitment to a science or engineering major, degree aspirations, and commitment to a science or engineering career (Wyer, 2001). While accurate information on science careers and personal contact with professional scientists can facilitate one's career exploration and decision-making, poor understanding of the nature of scientific careers may be contributing to the loss of student interest in science. According to Grandy (1998), the perceived compatibility between students' values and their aspired career impacts the persistence toward that career. The author noted that, sadly, a significant number of individuals have a poor appreciation of the contributions of science professionals since some reportedly transferred out of science and engineering because they would rather do something that will benefit society.

In the Seymour and Hewitt study (1997), inadequate advising, counseling, and tutoring were responsible in part for about one quarter of all student decisions to switch out of mathematics, science, and engineering majors, and were cited by three-quarters of the switchers as a source of frustration. About half of those who persisted in mathematics, science, and engineering studies expressed dissatisfaction with deficiencies in advising, counseling, and tutoring, since this was the second most frequently mentioned concern for this group. Students tended to describe their

advising and counseling experiences in such terms as “confusing,” “unreliable,” “inadequate,” and “impersonal.” They desired current information and advice about career options, graduate schools, scholarships, and interaction with professionals who could share their experiences about work (Seymour, 1995; Seymour & Hewitt, 1997).

According to one national study, 7 out of 10 students who completed engineering degrees in college had intentions of doing so when they were high school seniors (Adelman, 1998). Moreover, two national studies showed that the only significant recruitment to engineering comes from students who initially intended to major in the physical sciences (Adelman, 1998; Astin & Astin, 1992). This finding is not surprising given that success in attaining a mathematics-based or science-based college degree seems to depend greatly on a strong foundation of mathematics and science preparation. This suggests that while intervening strategies at the college level can enhance the retention of STEM majors, they are not likely to be very effective in the recruitment of new students into STEM fields. Instead, in order to substantially increase the number of STEM-degree recipients, especially those who have been traditionally underrepresented, there needs to be greater intervention at the pre-college level. Unfortunately, the underserved do not acquire a sufficient mathematics background prior to college entry and are essentially “eliminated from an inordinate number of careers ranging from . . . physical sciences and engineering to those in the social sciences and psychology” (Anderson, 1990, p. 264). In fact, the majority of American children (about 60%) and the bulk of minority children (about 85%) are channeled out of advanced mathematics and science when they are only 13 years old (Campbell, 1996).

The lack of early encouragement and motivation has been identified as one of the main reasons for the under-representation of African Americans in the natural sciences (see Pearson’s study as cited in Grandy, 1994). Pre-college summer seminar and career information have been shown to exert a greater influence on the choice of an engineering career for African American and Hispanic students than for White students. In a review of research on career development counseling for African Americans, Murry and Mosidi (1993) pointed to evidence suggesting that parental influence more heavily impacts the career choice attitudes of African American and Native American high school students than that of their White peers. Therefore, along with the use of role models and mentoring, early outreach career guidance programs for minority adolescents and their parents are recommended as an effective means of familiarizing students with a wider spectrum of college majors and career fields.

Learning Center

A growing number of campuses have seen the contributions that a learning center or drop-in center can make toward student achievement. Studying the growth and influence of learning centers, Sullivan (1980) noted that since the late 1960s and early 1970s there has been a growing movement in higher education institutions to create a unit, program, or facility specifically to assist students in strengthening the learning skills needed for academic achievement. A survey of 2,713 two-year and four-year institutions in North America revealed that approximately one-half operated at least one learning center program or unit (Sullivan, 1980). While learning centers can vary in name as well as function, they typically strive to facilitate student retention and performance, and often include elements related to instructional resources and media, learning skills enhancement, tutoring services, and pedagogical development. Very little research has been done on the effects of learning centers; however, observations of a relationship between their presence on campus and student learning have been documented. An article by Holton and Horton (1996) described the development and impact of the Physics Learning Center (PLC) at Rutgers University, later renamed the Mathematics and Science Learning Center. The Center offers lecture demonstrations that have been modified as permanent interactive exhibits, a study area, a physics library, tutors, test materials and course handouts, computers, and instructional videotapes on problem-solving and review sessions. Attracting more than 140,000 student visits a year, the Center became a place where faculty and teaching assistants hold office hours, study groups meet, workshops are presented, and undergraduate clubs are housed. The authors noted that the facility

became the setting where student performance and persistence were enhanced, and where “innovative, student-active, course development and experimentation” occurred (Holton & Horton, 1996, p. 140). In her review of intervention programs, Gándara (1999) noted that those which used learning centers as a major strategy emphasized them as a place in which students gather to form supportive networks involving peers and program staff, where learning tools are imparted, and where students can find sanctuary for study. The presence of a student study center was identified as a program component common to model minority engineering programs in a study by NACME (Matyas, 1991a).

Workshops and Seminars

Academic enhancement activities designed to impart knowledge and refine skills that are instrumental to college success have become prevalent on many campuses. The effectiveness of such seminars and workshops, however, has been little studied (Gándara, 1999). However, given a clear demand for such offerings, this type of academic support is often included in college-level intervention programs. A large proportion of minority students, including some with strong pre-collegiate educational records, struggle once in college in part because of feelings of isolation, and poor awareness of school policy, procedures, and support programs. African American students have self-reported poorer study skills in comparison to their White peers (Nettles, Thoeny & Gosman, 1986). Gallagher, Golin, and Kelleher (1992) found that African American college students, when compared with their White counterparts, expressed a greater need for assistance with study skills, reading skills, test-taking strategies, test anxiety, mathematics anxiety, and time-management skills. African Americans also displayed more concern with self-confidence, fear of failure, and relationships with faculty. African American males showed the most concern over career choice. Overall, African American college students appeared to be under a greater degree of stress than their White peers. A study by Novels and Ender (1988) found that minority students who participated in a series of three developmental modules with the themes of “University Awareness,” “Strategies for Successful College Study,” and “Career Exploration/Validation,” achieved higher college grades than did a historical comparison group.

Efforts to increase STEM graduate-degree attainment often involved assisting students with test-taking skills because graduate school admissions tend to place much emphasis on entrance examination scores. Research on test preparation for the Graduate Record Examination (GRE) has yielded evidence of positive effects that may be linked to test familiarization and test anxiety reduction (Powers, 1987; Swinton & Powers, 1983). Information about graduate programs, admission process, and financial aid opportunities, can greatly assist traditionally underrepresented students in their progress toward graduate school entry. In his study of Ford Foundation Minority Fellows, Solórzano (1993) found that many of these scholars experienced the lack of information and encouragement to continue on to graduate school as an obstacle that hindered their advancement from undergraduate to graduate studies.

Academic Advising

Quality academic advising has been described as the “cornerstone” of student retention (Dannells, Rivera, & Knall-Clark, 1992), and is a common strategy used in intervention programs that strive to reduce student attrition. Research suggested that quality academic advising positively impacts student retention as well as satisfaction with the institution (Backhus, 1989; Lowe & Toney, 2001; Pascarella & Terenzini, 2005). There is evidence to support that institutions with strong orientation programs and advising services have higher graduation rates than institutions without such emphasis (see Forrest’s study as cited in Pascarella & Terenzini, 1991). One study which controlled for academic ability, found that students’ chances of persisting increased with the number of counseling sessions they received (Wilson, Mason, & Ewing, 1997). Because student dissatisfaction with academic advising is high, especially among STEM students (Seymour &

Hewitt, 1997), and minority students are at a greater risk of dropping out of STEM majors, some have advocated the use of "intrusive" or "aggressive" advising with underrepresented populations (Matyas, 1991b; Velez, 2000). Intrusive advisement programs are based on the principle that students should be called in for advising numerous times during the school year instead of the standard once-a-semester meeting between a student and his or her advisor, or until a student displays serious academic difficulties. In one study, the implementation of an intrusive advising program coincided with positive outcomes such as, reduced freshmen attrition, higher mean-student grade point average, and more course hours attempted and completed by students. Because of a lack of controls, however, it is not clear what is attributable to the advisement program, and what resulted from other intervening programs (Glennen & Baxley, 1985).

Close contact with faculty and counselors has been identified as a key element of successful mathematics and science intervention models for underrepresented students (Rendon, 1985). According to Seymour and Hewitt (1997), the failure to elicit reassurance from faculty members that they are performing well, and have made a proper choice of science, has a disproportionately negative effect on both females and minority students because their confidence tends to be "neither strong, nor internalized, and is often tied to particular high school teachers who encouraged them" (Seymour, 1995, p. 201). Those students in the study who persisted in science, mathematics, and engineering (SME) majors expressed a strong appreciation for "faculty, professional advisors, departmental assistants, and teaching assistants who showed an active long-term interest in their learning, their problems and their progress" (Seymour, 1995, p. 202).

As the higher education student body becomes more diverse, academic advisors can play an increasingly crucial role in addressing the needs of nontraditional students. Possessing less of the "cultural capital" that provides familiarity with how to negotiate successfully through a university system, traditionally underrepresented students can benefit tremendously from quality academic advisement. In a recent study of factors that affect decisions of underrepresented minorities to forego science and engineering doctoral study, Brazziel and Brazziel (2001) found that each of the highly able interviewees mentioned poor advisement as a hindrance. In a study to assess the long-term effects on a cohort of African American students targeted for a special academic counseling program, Trippi and Cheatham (1991) found that while controlling for a range of variables, first-year, second-year, and third-year students who sought and received counselor assistance with legibility concerns (i.e., those pertaining to institutional culture, norms, and procedures) were consistently more likely to graduate than those who did not receive such assistance. In a study on academic advising, Lowe and Toney (2001) found no difference in the retention rates of those who were advised by faculty and those who were advised by staff advisors. A study on the personal, career, and learning skills needs of college students found that in terms of mode of receiving help, individual counseling was the most preferred method by the overall sample, and was more greatly preferred by African American students than by White students (Gallagher, Golin, & Kelleher, 1992).

In a review of the literature on educational advising, Creamer (1980) constructed an advising model for retention that recommended such steps as offering training programs for faculty or counselors with advising responsibilities, implementing a system for regular information flow to students which frequently updates academic progress, and promoting the development of frequent and meaningful interactions between faculty and students. A retention study conducted by NACME yields evidence that retention success of minority engineering students is related to the monitoring of student performance and early warning of academic difficulty (Penick & Morning, 1983). In their review of the literature on advising, Pascarella and Terenzini (2005) concluded that low-quality advising may be better than no advising and advising earlier is likely to be better than later.

Financial Support

Minority intervention programs tend to recognize the importance of providing financial support to students. In a national study of minority engineering students at 117 institutions by NACME, a

positive and significant relationship was found between minority retention rate and average financial aid awards (Georges, 1999). Similarly, a report by the U.S. Department of Education (2000) found science and engineering degree completion to be positively related to receiving financial aid from school. Holding constant a range of factors, students with families providing reliable financial support were more likely to complete a science or engineering degree. Although institutional research on the impact of student aid has yield mixed results, with some studies concluding aid to be effective and others concluding that it is not significant (Murdock, 1987), national studies have consistently found student aid to be a positive influence on persistence (St. John, 1991). In their analysis of data for a national sample of students, St. John, Kirshstein, and Noell (1991) found that with a range of background and college experience variables taken into account, financial aid exerts a positive effect on college persistence. Loans as well as grants and work significantly affected persistence.

In a meta-analysis of research studies on financial aid and persistence, Murdock (1987) found a positive albeit weak relationship. The impact of financial aid on persistence was greater for lower SES students than for middle-and high- SES students, greater for students at two-year institutions than four-year institutions, greater for those attending private than public institutions, and, greater in the later years than the initial years of college. The dramatic impact of scholarship aid (as opposed to loans) on the retention of low-income students was documented in a study by the U.S. General Accounting Office (as cited in Campbell, 1996). Among students from the poorest families, a shift of just \$1,000 from scholarship aid to loan reduced the probability of graduation by 17%.

Fenske, Porter, and DuBrock (2000) found that departure rates within SME were highest for underrepresented minorities and needy students. Underrepresented minorities in both SME and non-SME majors were less likely to finance their education with gift-aid only or self-help only packages; minorities tend to participate in more types of aid. For each of the five years of college in which data were analyzed, a high proportion of students with gift-aid only packages persisted the following year. A recent analysis on STEM students conducted by ACE found that completers came from families with higher incomes and that non-completers were more likely to work 15 hours or more a week (Anderson & Kim, 2006).

Curriculum and Instructional Reform

Much concern and criticism have been raised over the fact that despite the relatively strong academic backgrounds of freshmen with interest in mathematics, science, and engineering (Green, 1989; Seymour, 1992; Seymour & Hewitt, 1997), there continues to be a high attrition rate in these areas of study. While some may perceive the deficit in STEM majors as the natural outcome of a "weeding out" process of those who are incapable of handling a highly quantitative curriculum, more are coming to recognize that the heavy flow of talented students from these fields signals a systemic problem in STEM undergraduate education in this country. In an ethnographic study to investigate why college science fails to retain or attract students with the potential to become future scientists, Sheila Tobias (1990) recruited seven able postgraduates from the humanities and social sciences to "seriously audit" introductory science courses and to keep a journal of their experiences and observations. Encountering competition, a "tyranny of technique," and a lack of community in their science course, the auditors yearned for greater attention, support, and excitement. The main finding, according to Tobias (1993), is that

the physical sciences are presented in too narrow a teaching and learning mode and that, students with other strengths find little opportunity to use the skills they learn elsewhere, particularly their verbal skills, in making sense of the material. (p. 43)

Many have advocated curriculum reform as every year a large number of students are diverted out of the STEM pipeline through failure in gateway courses. There has been particularly great concern expressed over the quality of calculus education. An estimated third of all freshmen who

take calculus fail the course (Treisman, 1992). The nature of the "curricular structural impediments is complex," explained Treisman, and in cases like pre-calculus the "problems are essentially ones of coherence of the curriculum and its link or disconnectedness with what comes next" (Garland, 1993, p. 15). The calculus reform movement is said to have impacted nearly every institution of higher education in America (Bonsague & Drew, 1995), and typically involves the "use of technology," "real-life applications of the material," and "innovative teaching" (Alexander, Burda, & Millar, 1997). In a review of files on the 127 projects funded by the National Science Foundation's calculus initiative (1988-1994), Ganter (1997) found that the development of original curricular materials was the major goal of most projects, and that computer laboratory experiences, discovery learning, and technical writing were the most commonly employed instructional strategies. Acknowledging that curriculum reform is needed, John White of the National Science Foundation proposed integrating courses and combating the perception that mathematics and science are "sterile" and removed from the real world (Sheahan & White, 1990). In his model of institutional adaptation, developed from case studies of effective institutions to explain why some colleges and universities are more successful than others in improving minority participation, retention, and graduation, Richardson (1994) identified the most advanced response as that which includes significant curricular and pedagogical reform.

In their study, Keynes and Olson (2000) described the redesign of the calculus sequence at one research university as involving such key features as active learning, creative use of lecturing and other pedagogical methods, increase student/faculty contact, and increased use of group projects and workshop sessions. Participants of the calculus initiative achieved a higher average course grade and rate of course retention than did a comparison group enrolled in the standard calculus course. The researchers caution that curricular reform efforts that are purely content-based and which do not produce a more engaging environment tend not to yield as successful student outcomes. In an experimental study investigating the effectiveness of a revised undergraduate biology course, students enrolled in the experimental course (one which integrated lecture and laboratory sections, and adopted a learner-centered instructional model) scored higher on the attitude toward science survey and equally well on content knowledge acquisition when compared with students enrolled in the traditional course (McCormick, 2001).

The need to target pedagogical effectiveness in the reform movement is clear. In their ethnographic inquiry into science, mathematics, and engineering attrition, Seymour and Hewitt (1997) interviewed 335 undergraduates at seven institutions about their educational experiences, including those who stayed and those who transferred out of these fields. Of the range of concerns expressed by defectors and persisters, poor teaching by science, mathematics, and engineering faculty was the most often cited by both groups (90.2% and 73.7%, respectively). Furthermore, dissatisfaction with instruction was the third most frequently mentioned factor in switching decisions, and had contributed to more than one-third of such decisions. Students lamented about the "counterproductive" effects of faculty's emphasis on "weeding out" rather than on "support and encouragement" (Seymour & Hewitt, 1997). In a study involving a nationally representative sample of college freshmen, Hagedorn, Siadat, Nora, and Pascarella (1997) found that perceived teaching quality by students significantly and positively predicts mathematics gain. The importance of quality of instruction is also emphasized in a national study by Hilton et al. (1989) on the persistence of high-ability minority students in college science. This study found that persisters, in comparison to nonpersisters, view science, math, and engineering study to be more enjoyable, interesting, and rewarding.

In a 1992 study involving a national sample of undergraduates at 388 institutions, Astin and Astin found that a strong research-oriented faculty negatively impacted persistence among physical science majors; the authors surmised that this was due in part to the heavy reliance on teaching assistants in undergraduate science coursework. In contrast, a strong student-oriented faculty positively impacted students' aspirations for research careers and persistence in the biological sciences. Investigating why high-ability minority students are choosing not to pursue SME fields, Brown and Clewell (1998) interviewed 135 African American and Latino non-science majors (most of who had SAT I mathematics scores of 600 or above). The researchers found that

the top three most influential factors pertain to teachers' attitudes and behaviors (non-SME teachers were perceived as being more caring and encouraging, whereas SME teachers tended to be seen as being "arrogant, unavailable, or unapproachable"); teaching practices (non-SME teachers were considered to be more effective in presenting the subject matter); and, course or curriculum issues (students were turned off by the longer time-to-degree, restrictive curriculum, time-consuming workload, and intense competitiveness associated with SME).

AN INTEGRATED APPROACH

An accumulated body of research suggested that STEM intervention programs for underrepresented students work best if they employ an integrated approach. In a report by BEST (Building Engineering & Science Talent, 2004), which draws on the systematic review work of an expert panel, eight design principles that underpin exemplary and promising higher education-based STEM interventions were identified: (a) institutional leadership, (b) targeted recruitment, (c) engaged faculty, (d) personal attention, (e) peer support, (f) enriched research experience, (g) bridging to the next level, and (h) continuous evaluation. Similarly, a 1985 study by NACME (see Matyas, 1991a) found that exemplary minority engineering programs tackle both academic and attitudinal barriers, and tend to contain the following components:

- student recruitment from high schools and two-year colleges;
- assistance with admission procedures;
- assistance with student matriculation (including procuring financial aid, academic advising, orientation);
- academic support services (tutoring, study skills training, extra recitations);
- student study center;
- linkage of students with minority student organizations in engineering; and
- summer engineering jobs.

In a study that examines institutional practices that positively affect the retention of minority students on predominantly White campuses, Clewell and Ficklen (1987) conducted intensive case studies of four colleges and universities with high minority retention rates. These researchers found that all four institutions had effective retention programs that were deemed comprehensive in their offering of services.

There are a number of national STEM intervention programs that adopt an integrated approach to battling the impediments to greater and more diverse participation in STEM. These programs recognize that multiple strategies are needed to combat the diversity of barriers that hinder the progress of underrepresented groups along the STEM pathway. Three such programs—Meyerhoff Scholars Program, Minority Engineering Program, and the Mathematics Workshop Program—are highlighted in this article. These programs were chosen because they are well-known, have empirical data to substantiate their effectiveness, and have been either widely replicated or influential to the development of many other programs.

Meyerhoff Program

The Meyerhoff Program is a comprehensive intervention program located at the University of Maryland Baltimore County that is designed to address four critical areas suggested by the research literature as inhibiting minority success in science: (a) knowledge and skills, (b) motivation and support, (c) monitoring and advising, (d) and academic and social integration. Top mathematics and science African American students are selected for participation and are exposed to such program components as summer bridge (mathematics, science, and humanities coursework and training in analytical problem-solving); scholarships (four-year comprehensive contingent on maintaining at least a B average); academic advising and personal counseling; tutoring; study groups; summer research internships in science and engineering; mentoring by scientific professionals; and, faculty and family involvement. A strong family-like program community is

fostered through regular group meetings of staff and students and a shared residence hall for freshman Scholars. The program has supported 768 students, 260 of whom are currently undergraduates (Summers & Hrabowski, 2006).

In a study that compares first-year academic outcomes of the first three cohorts of Meyerhoff students with a historical sample of comparably talented African American science students at the university, Hrabowski and Maton (1995) found that controlling for key background variables, Meyerhoff students achieved both a higher mean overall GPA (3.5 vs. 2.8) and a higher mean science GPA (3.4 vs. 2.4). Observational and survey questionnaire data suggested that study groups, a peer-based community, financial scholarships, summer bridge program, and the collaborative efforts of staff and faculty were particularly relevant to participant success.

Extending their previous research, Maton, Hrabowski, and Schmitt (2000) investigated the longer-term participant impact of the Meyerhoff Program and factors that lead to program effectiveness. Academic outcomes five years after college entry were compared for three cohorts of Meyerhoff students and multiple comparison groups (including SME students who declined the Meyerhoff scholarship, a historical cohort of comparable students, and a contemporary comparison group). Results showed that Meyerhoff students generally earned higher grades in SME, graduated with SME degrees at a higher rate, and attended graduate school in SME fields at a higher rate than did the comparison groups. Furthermore, interview data indicated that as a result of the program, positive ripple effects of science education were felt at the institution, and faculty underwent a "dramatic, positive change in perceptions and expectations concerning African American student performance in science" (Maton, Hrabowski, & Schmitt, 2000, p. 647). A more recent article echoes many of these findings (Summers & Hrabowski, 2006).

Fries-Britt (1998) conducted extensive interviews with twelve Meyerhoff Scholars in their senior year to learn more about their academic, social, and racial experiences. She found that similar to many other top African American students, those in her study had little exposure to other academically gifted African American students. According to Fries-Britt, the Meyerhoff program represented the first time that these students were "surrounded by a large number of high-achieving Blacks who were striving toward the same goal of academic excellence" (p. 564). She concluded that participation in the Meyerhoff program provided an emotionally supportive, family-like environment that facilitated peer networking, and consequently helped ward off feelings of marginalization. Student isolation and non-assimilation are of particular concern in cases where minority students attend a large, predominantly White university.

Minority Engineering Program

A well-established and widely replicated program is the Minority Engineering Program (MEP), which is the college-level extension of the MESA (Mathematics, Engineering, and Science Achievement) program that operates at the secondary school level. Founded in 1973 by Ray Landis, an engineering professor at the California State University, Northridge, the MEP model has been propagated at more than 100 universities and privately sponsored programs (May & Chubin, 2003). While MEPs are located on a variety of campuses, and vary somewhat in program features, they tend to share some common elements: linkage with the engineering unit of the institution; strong pre-college and community college outreach; concentrated efforts on working with freshmen and sophomores; an emphasis on cooperative learning and community building through the use of structured collaborative study groups, the clustering of MEP students in the same sections of courses, and the establishment of study centers; professional development activities such as role model speakers and industry field trips; and, the offering of such academic support services as freshmen orientation courses, tutoring, summer bridge, supplemental instruction in mathematics and science, close monitoring of student progress, and academic and personal counseling (Collea, 1990; Landis, 1988; Morrison & Williams, 1993).

Gains in student learning and retention in engineering studies have been reported for MEP participants (Rotberg, 1990). In response to a request by the California legislature to assess the impact of MEP, the California State Postsecondary Education Commission (1986) issued a report

that showed MEP participants continue in engineering at a higher rate than non-participants. The results were especially encouraging for the four ethnic groups targeted by the program (African Americans, Mexican Americans, other Hispanics, and Native Americans). Examining three-year retention data for engineering students at the University of California campuses and the California State University campuses, Landis (1988) found that the retention rate for minority students who participated in the MEP exceeded not only that of minority students who did not participate in the MEP, but also that of the overall student group in engineering.

Gándara (1999) cited improved retention rate data for the MEP at the California State University, Sacramento which experienced an increased 10% per year more than four years—beginning with 50% in 1991 and growing to 80% by 1994. In a study of the impact of the MEPs at Florida Agricultural and Mechanical University-Florida State University (FAMU-FSU), Ohland and Zhang (2002) found that after controlling for high school GPA, MEP students were more apt to graduate in engineering than non-MEP counterparts though the results were not statistically significant. Another study found that the higher retention rate of African American MEP students, in comparison to non MEP African American engineering students, at one institution was associated with a greater sense of connectedness to the engineering community (Good, Halpin, & Halpin, 2002). The MEPs of certain universities have also been credited with their institution's success at graduating high numbers of underrepresented students. MEPs have been highlighted in a study that examines the top ten institutions that are most successful at preparing underrepresented minorities for doctoral study in science and engineering (Brazziel & Brazziel, 1997), as well as in a study of four predominately White campuses with exceptionally high minority retention rates (Clewell & Ficklen, 1987).

Since the creation of the Minority Engineering Program, minority enrollment in engineering has climbed substantially, but attrition remains high (Morrison & Williams, 1993). Therefore, merely having a program on campus does not guarantee success. Just as program implementation varies, so does program effectiveness (Richardson, 1994). In a study examining MEPs at 20 engineering schools, Morrison and Williams (1993) found that the eight MEPs that were the most successful in recruiting and graduating minority students tended to have strong recruitment through high school outreach, provided summer programs that strengthen content knowledge and emphasize study and critical thinking skills, were perceived as having high faculty support, offered study centers, were equipped with an adequate number of tutors, and received relatively high levels of institutional funding.

The Mathematics Workshop

One of the most well-known and modeled after intervention programs is the Mathematics Workshop Program (MWP). Work on the MWP model began in 1974 when Uri Treisman conducted an informal observational study to explain group performance differences in first-year calculus students. Treisman (1992) found that group performance was linked to strategy differences in examination preparation and homework completion. More specifically he found that informal "study groups" effectively aided the exchange of academic and institutional information, and expedited mastery of subject matter as "students checked each other's work, pointed out errors in each others' solutions, and freely offered each other any insights that they had obtained . . . about how to manage difficult problems" (Fullilove & Treisman, 1990, pp. 466-467).

MWP was purposefully designed as an honors program to combat "debilitating patterns of isolation by emphasizing group learning and a community life focused on a shared interest in mathematics" (Treisman, 1992, p. 368). As a complement to the calculus course, an "intensive" workshop was offered in which groups of five to seven students collaboratively tackled challenging and carefully crafted problems for two hours twice a week. A graduate student workshop leader monitored the process and strategically guided participants through difficulties. According to Treisman (1992), the heart of the project lies with the problem sets which fuel group interaction as students are given "plenty of opportunities for self-correction and an environment in

which they could safely make public their understandings" (Garland, 1993, p. 14). Along with an emphasis on academic excellence and enrichment, the program also offered within the academic setting a range of support services such as counseling, monitoring of academic progress, and assisting with navigating the university system (Clewell, 1989).

Program evaluation results showed that workshop participants, when compared with non-participants, were more likely to persist and to graduate, in addition to being two to three times more likely to earn higher mathematics grades (Fullilove & Treisman, 1990). Moreover, African American and Latino/a participants outperformed not only their non-workshop minority peers, but also their non-workshop White and Asian classmates. African American students with Mathematics SAT scores in the low-600s performed as well as White and Asian students with Mathematics SAT scores in the mid-700s (Treisman, 1992). These results are even more impressive when one considered the academic records of minority students prior to the creation of the program. African American and Latino/a students had grades far below the average; more than one-fourth of the minority students who attempted Mathematics I-A dropped the class; and, after failing the mathematics sequence, a significant number of minorities withdrew from the institution (Clewell, 1989). Qualitative study of the program suggested that the superior outcomes of workshop participants may be due to greater time spent on mathematics study, which is shown to be a significant and positive predictor of mathematics gain (Hagedorn, Siadat, Nora, & Pascarella, 1997), as well as the more efficient manner of study that purportedly occurs in these study groups (Fullilove & Treisman, 1990).

The mathematics workshop model has inspired other sites to adopt similar programs such as the Emerging Scholars Program at the University of Texas at Austin, the Academic Excellence Workshop at the California State Polytechnic University (Pomona), the Merit Workshop Calculus Program at the University of Illinois at Urbana-Champaign, and the Wisconsin Emerging Scholars Program at the University of Wisconsin, which have all shown evidence of positive effects on student participants including higher grades, lower rates of course repetition, greater chance of enrolling in further mathematics coursework, and choosing and persisting in a STEM major (Alexander, Burda, & Miller, 1997; Bonsangue & Drew, 1995; Moreno & Muller, 1999; Murphy, Stafford, & McCreary, 1998).

CONCLUSION

In order for the U.S. to maintain its preeminence in the world economy of this new millennium, in which science-based fields are playing an increasingly prominent role, educators need to expand and diversify the STEM talent pool. The urgency of this challenge is underscored by the amount of effort and funding invested in an array of interventions to increase the quality and quantity of students choosing and persisting in STEM fields. To ensure that these diversity efforts are paying off, investigation into their efficacy needs to be pursued. This review and synthesis of the research literature on effective strategies reveals the mounting evidence on ten commonly adopted strategies. From the overall, results some recommendations to guide future action and research can be drawn.

This review yields a sense of where empirical evidence is accumulating, and consequently, where more study is needed. Of the ten strategies examined, some have received more research attention than others. For instance, research experience and mentorship have been the subjects of more research study than summer bridge programs, learning centers, workshops and seminars, and academic advising. While there is relatively less empirical evidence to substantiate the efficacy of these latter strategies, their popular use would suggest that educators and researchers who implement them might be judging them effective through informal study or casual observation.

The results of this review also suggest that what has been found to be effective for underrepresented minority students overlaps with what is known to be beneficial for the overall student population (e.g., tutoring, internships, faculty-mentored research, quality advisement, and so forth) in terms of a range of desired student outcomes (National Survey of Student Engagement, 2003; Pascarella & Terenzini, 2005), including but not limited to students' interest,

satisfaction, and retention in STEM studies (Astin & Astin, 1992). This is an important point because it means that schools and departments can largely focus their efforts on pursuing a set of strategies that benefit not only underrepresented minorities, but also, the STEM student body at large. This is particularly salient because intervention programs for minorities are increasingly called into question and even legally challenged ("M.I.T. to open two programs," 2003; Winter, 2003). There is some reason to believe that STEM enrichment programs made available to all students work better for underrepresented minorities and women because they avoid stigmatization and "spotlighting" (Bonsangue & Drew, 1995; Campbell Jolly, Hoey, & Perlman, 2002; Knight & Cunningham, 2004; McLoughlin, 2005; Seymour & Hewitt, 1997).

The results here also suggest that those who fund, design, and implement intervention efforts should strive for an integrated approach by employing a combination of strategies. Clearly, given what is known from research about the range of barriers that impede student persistence in STEM fields, accumulating evidence of the efficacy of a number of common strategies, and substantial empirical support for some established programs (such as the three highlighted in this article), one can surmise that programmatic interventions employing an arsenal of strategies are more apt to succeed. This is probably because a holistic approach optimizes the chance that students will be provided with the academic, social, and professional development support they need to progress further along the STEM pathway.

On the scholarly front, more quality empirical research is needed. In conducting this review, the bulk of the writing located on this subject area was of a descriptive nature (i.e., descriptions of intervention programs with no data gathered to study the effects resulting from the intervention efforts). Only a small portion of the existing literature actually involves empirical evidence. Although evaluations of programs are becoming more commonplace, evaluation results are not always published, and therefore, difficult to access (Ginorio & Grignon, 2000). Comprehensive or intensive evaluations of programmatic interventions can and should contribute to the knowledge base by publishing and disseminating their results.

Federal and national programs, in particular, are especially situated to further the knowledge base because of the large number of student and institutional participants involved, wide range of variables (including demographic, program features, outcomes) on which data are or can be collected, and program longevity. The far-reach and breadth of offerings within national programs places them in a unique position to investigate both short- and long-term student outcomes. What is needed, however, is coordinated data collection across projects and an efficient and effective tracking system of participating students. Longitudinal studies of national programs can greatly advance the understanding by illuminating what is and is not working at the national level, as well as within varying local contexts and conditions.

Furthermore, researchers and evaluators should make special efforts to investigate the relative impact of various strategies. This would be particularly beneficial given that budget constraints prevent the most committed program directors and schools from adopting as many strategies as they otherwise would. However, it is difficult to discern how the "effective" strategies identified in this review measure with one another because there has been little systemic attempt by researchers to compare and contrast the effectiveness of various strategies within a single study. One notable exception is the evaluation of the National Science Foundation's LSAMP (Louis Stokes' Alliances for Minority Participation) Program, in which projects typically implement a range of intervention strategies. Study findings revealed that among the major program components involved, three stand out as having a significant positive relationship with the desired student outcomes of enrollment in and completion of graduate degrees: (a) research with faculty, (b) internships, and (c) summer bridge (Clewell, Consentino de Cohen, Tsui, & Deterding, 2006).

Finally, now that a certain body of evidence has accumulated on effective strategies, one needs to work toward identifying what works for whom and under what contextual or institutional conditions. In other words, it is necessary to move beyond "what" (works), and toward "for whom," "why," and "how." Mixed-methods studies that involve both quantitative and qualitative components might be most suitable for this task. Quantitative analyses lend themselves to

investigating “what” and “for whom.” While “why” and “how” questions can perhaps be best examined through ethnographic study and the richness of qualitative data. Results of such studies will help inform both the policymaking and local program decision-making that anchor the vital endeavor to broaden and enhance the national STEM capabilities.

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