Designing for Success

Positive factors that support success in STEM pathways and reduce barriers to participation: what does the research say about what enables students to succeed and persist in STEM fields?

Research has identified a number of positive factors that help students successfully enter Science, Technology, Engineering and Mathematics (STEM) fields and persist in educational and professional pathways to full blown STEM careers. Faculty can design for student success by designing programs that adapt and adopt practices that cultivate these positive factors in program environments and curricula. This article highlights 17 positive factors, offers examples of intentional and successful implementation of these factors in current and past programs, and provides references for further reading.

The Institute for Broadening Participation's mission is to increase diversity in the Science, Technology, Engineering and Mathematics (STEM) workforce. We design and implement strategies to increase access to STEM education, funding, and careers, with special emphasis on reaching underserved communities and diverse underrepresented groups.

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Early exposure to STEM fields in K-12

"Early" is early enough in the primary education years to influence interest in and choice to take STEM courses when the opportunity arises. Research 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; cited in Museus et al. 2011). Early interest in science is positively related to students' desire to major in science in college (Hall and Post-Kammer 1978, cited in Museus et al. 2011).

For example: "Moore's qualitative study (*2006) of forty-two Black engineering students who attended a PWI [primarily white institution] found that having a passion for engineering and mathematics in primary and secondary school contributed to their persistence in higher education" (cited in Museus et al. 2011).

***Antithesis or barrier**: **Limited academic experiences in mathematics and science prior to high school** negatively affects interest in and access to STEM occupations. For example: "Hispanic students with limited participation in early childhood educational programs are more likely to move through the K-8 mathematics curriculum at substantially slower rates than white students (Gross 1993, 8), leading to limited opportunities to participate in advanced coursework in mathematics" (Clewell and Anderson 1991; Swail, Cabrera et al. 2005; cited in Crisp and Nora 2006).*

Family support

Having parents who are STEM professionals is correlated with success in STEM education (Astin and Astin 1992; Grandy 1994). Parental expectations and involvement can facilitate the success of racial and ethnic minority students in STEM courses and academic pathways (Fries-Britt, Younger and Hall 2010; Hrabowski 2003; *Hrabowski and Maton 1995; Russell and Atwater 2005; Smith and Hausfaus 1998; cited in Museus et al.

2011). Parental encouragement is one of the strongest influences on Hispanic students' early educational aspirations (*Arbona & Nora 2005, cited in Crisp and Nora 2006).

For example: "Hispanic males living in a household where at least one parent is engaged in engineering or physical science as an occupation are more likely to select engineering as a major (Leslie, McClure and Oaxaca, 1998). [Researchers] concluded that having a parent working in an engineering or science-related field is instrumental in forming the belief among Hispanic males that a career in STEM is a realistic goal" (cited in Crisp and Nora 2006).

Antithesis or barrier: Lack of college awareness. *For example, first generation college students and their families may lack basic information and preparation for the college application and matriculation process (National Academies 2011).*

Authentic science engagement

Authentic science engagement (i.e. via discovery-based research courses or independent research on faculty projects, as opposed to standard laboratory courses) encourages individual ownership of projects and provides "a direct way for students to experience real discovery and innovation and to be inspired by STEM subjects" (President's Council of Advisors on Science and Technology (PCAST) 2012). "Findings provided by the Educational Testing Service (1989) note that when high achieving minority students perceive their science, mathematics or engineering coursework as enjoyable, those students are much more likely to persist in their chosen field" (Barton 2003, cited in Crisp and Nora 2006).

Do it: "For the past decade, engineering schools have developed a variety of models for introducing first-year students to their chosen field. These range from surveys of a selection of engineering disciplines and introductions to problem solving and algorithmic thinking, to design and professional skills in project-based learning courses. Such courses have greatly enhanced the participants' early understanding of the engineering field. This improved understanding of the field has helped students make better choices of disciplines and, consequently, increased their satisfaction with their engineering education" (Sheppard 2009, cited in Meadows, Fowler, and Hildinger 2012).

***Antithesis or barrier*: *Uninspiring introductory courses*.** *High-performing students frequently cite uninspiring introductory courses as a factor in their choice to switch majors: "Traditional introductory laboratory courses generally do not capture the creativity of STEM disciplines. They often involve repeating classical experiments to reproduce known results, rather than engaging students in experiments with the possibility of true discovery. Students may infer from such courses that STEM fields involve repeating what is known to have worked in the past rather than exploring the unknown." (President's Council of Advisors on Science and Technology (PCAST) 2012).*

Active learning

Evidence-based teaching methods that engage students in 'active learning' by integrating hands-on learning and laboratory instruction (as opposed to lecturing) "improve retention of information and critical thinking skills . . . and increase persistence of students in STEM majors" (President's Council of Advisors on Science and Technology (PCAST) 2012). Several studies cite the positive influence of active learning on students' educational experiences (Smith et al. 2005; *Heller et al. 2010).

Antithesis or barrier: "Traditional approaches to teaching and learning can suppress and smother interest and creativity *among many students who do not have resilience or support after early failures or disappointing experiences in STEM subjects. Accordingly, some students dismiss themselves from STEM subjects, majors, and careers based on experiences, and sometimes only a single experience, even before they have fully transitioned from pre-adolescent, concrete-operational thought to the capacity for abstract thinking that allows them to fully appreciate these subject areas." (Egenrieder 2010)*

Do it: "Educators and others, in both formal and informal settings, can foster students' continued interest and resiliency in STEM education subjects, majors and careers through student-driven project-based learning . . . Regular opportunities for authentic student-led inquiry provide opportunities to renew or expand interest in technical explorations and distinctions that foster the resilience, creativity, and curiosity necessary for successful STEM careers, particularly as young people begin to define and refine their identity and self-perceptions. This resilience remains important through high school, college 'weed-out' courses, and during job searches or in considering graduate programs, when so many prospective scientists and engineers switch to other academic and career paths." (Egenrieder 2010)

Culturally relevant pedagogy and science relevancy

Culturally relevant pedagogy recognizes that all students bring their culturally influenced cognition, behavior and dispositions with them to school, and deliberately seeks to connect curriculum, instruction, and assessment to students' experiences, cultures, and traditions. Science relevancy occurs and creates a positive reinforcement to go into STEM when students can utilize their science to investigate something relevant to their communities. Scholars indicate that incorporating culturally relevant pedagogy into science and mathematics instruction has had a positive impact on success in STEM fields for African American students (Denson, Avery, and Schell 2010; Ladson-Billings 1995; Lipman 1995; Shujaa 1995; *Tate 1994, 1995a); Native American students (Nelson-Barber and Estrin 1995); Hispanic students (Rolon 2003); and Southeast Asian American students (*Kiang 1997, 2002).

Do it: Culturally relevant instructional behaviors include, for example: learn more about building on students' interests and linguistic resources; learn more about tapping community and home resources; help students examine the curriculum from multiple perspectives; learn more about using a variety of valid assessment practices that promote learning; use examples and analogies from students' lives; develop positive relationships with parents and community; help students find meaning and purpose in what is to be learned; prepare students to effect changes in society; and help learners construct meaning by organizing, elaborating, and representing knowledge in their own way (Villegas and Lucas 2002; Irvine and Armento 2001; cited by Southern Poverty Law Center 2013).

Antithesis or barrier: Perceived lack of clear social purpose for STEM careers*. "Most people do not view STEM occupations as directly benefiting society or individuals. As a result, many STEM careers often do not appeal to women (or men) who value making a social contribution" (Hill, Corbett, and St. Rose 2010)*.

Antithesis or barrier: Cultural incompatibility *between students and their school can result in negative outcomes such as "miscommunication; confrontations among the student, the teacher, and the home; hostility; alienation; diminished self-esteem; and possibly school failure" (Southern Poverty Law Center 2013).*

Resiliency

Resiliency is the ability to continue forward in the face of current, recent or historical adversity, personal failure or negatively erroneous expectations; "the human capacity of all individuals to transform and change, no matter what their risks" (Lifton 1994); or an innate 'self-righting mechanism' (Werner and Smith 1992). 'Resilience skills' include the ability to form relationships (social competence), to problem solve (metacognition), to develop a sense of identity (autonomy), and to plan and hope (a sense of purpose and future) (Center for Mental Health in Schools at UCLA 2008). Resiliency is an individual's ability to overcome life's obstacles and continue on with their development: "as the person grows older, for example, their resilience is supported by their capacity to use family, community and cultural ways to access resources for their health and well being. Resilience, therefore, is an ability to solve problems, which ability stems from a belief in one's self. It is an ability to live life in the face of uncertainty, with empathy for others, while having goals and aspirations and finding the balance between independence and dependence" (Kutzner 2008). A common finding in resilience research is the power of teachers to tip the scale from risk to resilience (Center for Mental Health in Schools at UCLA 2008), by engaging in or creating three factors: caring relationships (Higgins 1994; Meier 1995); positive and high expectations (*Delpit 1996); and opportunities to participate and contribute (Rutter et al. 1979; Rutter 1984; Kohn 1993). Thompson (1998) identified factors that facilitate the resilience and achievement of successful African American students, which include effective and supportive teaching.

Do it: "When we looked at the data we found that in the preceding decade 60% of the Black students who enrolled in and completed first-term calculus at Berkeley received grades of D or F . . . In 1978 we began to experiment with solutions . . . In response to the debilitating patterns of isolation that we had observed among Black students . . . we emphasized group learning and a community life focused on a shared interest in mathematics. We offered an intensive 'workshop' course as an adjunct to the regular course . . . we provided our students with a challenging, yet emotionally supportive academic environment . . . [T]he real core was the problem sets which drove the group interaction . . . We were able to convince the students in our orientation that success in college would require them to work with their peers, to create for themselves a community based on shared intellectual interests and common professional aims . . . The results of the program were quite dramatic. Black and Latino participants, typically more than half of all such students enrolled in calculus, substantially outperformed not only their minority peers, but their White and Asian classmates as well."(Treisman 1992)

Do it: The **Significant Opportunities in Atmospheric Research and Science (SOARS®)** program is a multiyear mentoring program that brings together students majoring in sciences, engineering, mathematics, and related social sciences for 10 weeks of intensive research each summer, during which it provides a framework for inspired performance and resiliency: "SOARS tries to inspire protégés to take on tasks that may require new skills. In many cases, growth can only occur outside an individual's comfort zone, and learning to work effectively outside one's comfort zone helps the protégé develop perseverance and skills, sometimes in the face of anxiety and overload. These same skills translate well to surviving graduate school and later life" (Windham, Stevermer, and Anthes 2004). From 1996 to 2012, 118 out of 138 SOARS protégés who had completed their undergraduate degree had earned undergraduate degrees in Science or Engineering (UCAR/SOARS 2012).

Self-efficacy in STEM subjects

Self-efficacy in STEM is belief in the potential for one's own intellectual growth – the confidence in one's ability to learn and succeed, in math, science and engineering. Self-efficacy has been shown to be a salient predictor of performance and success in STEM education (Colbeck, Cabrera, and Terenzini 2001; Perna et al. 2009; Stevens et al. 2004). Leslie, McClure, and Oaxaca (1998) found that the probability of choosing engineering or science increases with students' perceptions that they possess solid science or math background and in the belief that they have the ability to perform well in those courses. "Individuals must believe they have the ability to succeed in a given career to develop preferences for that career . . . if [they] do not believe they have the ability to become a scientist or engineer, they will choose to be something else" (Hill, Corbett, and St. Rose 2010). **For example:** Correll (2001), controlling for actual ability, "found that the higher students assessed their mathematical ability, the greater the odds were that they would enroll in a high school calculus course and choose a college major in science, math, or engineering. She also found that

Antithesis or barrier: Low self-efficacy. *Correll (2004) verified "in a laboratory experiment that when cultural beliefs about male superiority exist in any area, even a fictitious one, girls assess their abilities in that area lower, judge themselves by a higher standard, and express less of a desire to pursue a career in that area than boys do" (cited in Hill, Corbett, and St. Rose 2010). Leslie, McClure and Oaxaca (1998) observed that minority students have lower self-efficacy when it comes to science and mathematics as compared to white students. Stevens et al. (2004) substantiated this finding with a Hispanic student population.*

boys were more likely than their equally accomplished female peers to enroll in calculus not because boys were better at math but because they believed that they were better at math" (cited in Hill, Corbett, and St. Rose 2010).

Do it: Interventions designed to psychologically combat negative stereotypes can reduce or eliminate the negative impacts of low self-efficacy or stereotype threat. For example, Aronson, Good, and Inzlicht (2003) "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" (as cited in Museus et al. 2011).

***Antithesis or barrier: Stereotype threat** is the experience of anxiety or concern in a situation where a person has the potential to confirm a negative stereotype about their social group. Stereotype threat can occur whenever an individual's performance might confirm a negative stereotype, and has been shown to reduce the performance of individuals who belong to negatively stereotyped groups. "Research shows that stereotype threat may account for the academic outcomes of females in mathematic courses [Inzlicht and Ben-Zeev 2000; Aronson, Good, 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]" (cited in Museus et al. 2011). One study showed that women "experienced a greater deficit in their math performance the more males there are in their environment" and that "merely placing high-achieving females in a stereotyped setting, in which they are in contact with males, causes a decrease in their performance," a result that highlights "the indirect environmental effects of negative stereotypes on the targets of these stereotypes" (Inzlicht and Ben-Zeev 2000). Another study showed that when women were even subtly reminded of the stereotype that men were better than women at math, the performance of women in math tests measurably declined (Steele, Quinn, and Spencer 1999).*

Adequate academic preparation in high school for college-level work in STEM

"Many studies indicate 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; cited in Museus et al. 2011). "The number of mathematics, science, and English courses taken by high school students serves as a major predictor of choosing a college major in the sciences, technology, engineering or mathematics, and is related to student persistence" (Astin and Astin 1992; Simpson 2001; cited in Crisp and Nora 2006). "The math and science courses that students take before college

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determine who will receive further training in STEM fields" (*Anderson 1996; Astin and Astin 1992; Chang et al. 2008; Denson, Avery, and Schell 2010; Fenske, Porter, and DuBrock 2000; Maple and Stage 1991; Maton, Hrabowski, and Schmitt 2000; National Science Foundation 2006; cited in Museus et al. 2011). "Mathematics preparation prior to enrollment in college has been found to positively impact students' interest in science as a major and future career [Astin and Astin 1992] and has been shown to hold true for minority students specifically [Grandy 1998]" (cited in Crisp and Nora 2006).

Antithesis or barrier: Insufficient academic preparation *is tied to failure to succeed and persist in STEM fields (Anderson and Kim 2006). For example, students with a high interest and aptitude in STEM careers, but with low-performing math skills, often have difficulty with the math required in introductory STEM courses with little help provided by their universities* (*President's Council of Advisors on Science and Technology (PCAST) 2012).*

Undergraduate STEM courses within the first two years of college

STEM courses during the first two years of college have an enormous effect on the knowledge, skills, and attitudes of future K-12 teachers (President's Council of Advisors on Science and Technology (PCAST) 2012). "Grandy (1998) emphatically notes that students' enthusiasm for engineering and science either builds or weakens during the freshman and sophomore years" (as cited in Crisp and Nora 2006).

Role models

Role model: a person whose behavior, example, or success is or can be emulated by others, especially by younger people (Dictionary.com 2013). "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, cited in Museus et al. 2011).

Antithesis or barrier: Bias in historical representation of minorities in science. "*Textbooks may overlook URMs in science" (National Academies 2011).*

Do it: "One researcher found that simply reading to students biographies of scientists from underrepresented groups increased science aspiration" (National Academies 2011). Visit **The History Makers: ScienceMakers** website (www.thehistorymakers.com/makers/sciencemakers), which profiles 180 of the United States' top African American scientists as positive role models, presenting their life stories as a way to encourage others to enter scientific professions.

Mentors & Mentoring

Mentoring relationships have been shown to positively impact student success and retention. Mentoring is an intentional relationship or partnership, focused on the needs of the mentee, which encourages individuals to develop to their fullest potential. A mentor is invested in their mentee's success and provides guidance on an ongoing basis, perhaps helping with exploring careers, setting goals, developing contacts, and identifying resources. The mentor role may change as the needs of the mentee change. Mentoring can take many forms: one-on-one, faculty-to-student, peer-to-peer, group, e-mentoring, a shorter-term mentoring match at a conference, or a long term mentoring relationship that is deep, and strong,

Do it: Use the **Institute for Broadening Participation's *Online Mentoring Manual*** (www.pathwaystoscience.org/manual.aspx) to increase your understanding of mentoring and access tips on areas of mentoring responsibility such as: creating a mentoring environment; calibrating your mentoring to meet mentee needs; balancing challenge and support; virtual mentoring; and maintaining a long term relationship with your mentee. Recommend the manual to your students to help them take responsibility for becoming better mentees and future and lasts for life. Mentoring relationships may occur in structured programs with specific expectations and guidelines or on a more informal basis. Engaged mentors can provide undergraduates, graduate students, and early career faculty with information, advice, guidance and support both in general and at critical decision points (George et al. 2001; MENTOR 2009; National Research Council 2011). **For example:** "Although not from a formal mentoring perspective, Grandy (1998) found that the most important variable impacting high-ability minority students' science ambition and persistence in the major was the support they received from minority 'mentors' which they defined as having a minority role model in college (e.g. science faculty, doctoral students), receiving different forms of support from advanced undergraduate students of the same ethnic group, and having access to a dedicated minority relations staff" (cited in Crisp and Nora 2006).

Do it: Partners for Youth with Disabilities (PYD) Mentor Match Program is a one-to-one face-to-face mentorship program specifically focused on youth with disabilities between the ages of six and 24 years old. Mentors and mentees agree to a one- year commitment, see each other at least once per month, and have phone contact once per week. PYD has noted the need for mentoring programs that are not currently serving youth with disabilities to become more inclusive of youth with disabilities. Youth with disabilities can thrive in general mentoring programs that develop a comprehensive training for mentors and educate mentoring staff. (National Collaborative on Workforce and Disability for Youth (NCWD/Youth) 2006)

Campus & classroom culture and climate

"In response to early studies showing low retention rates in engineering, many researchers worked to identify associated cognitive factors. For example, Seymour and Hewitt [1997] found that decisions to stay or leave engineering were not related to high school GPA or other demographic factors . . . [and] concluded that classroom instruction methods, departmental culture, and institutional structure were the primary reasons for student departure, specifically citing misalignment of these cues with student intentions. [Lichtenstein et al. 2007] expanded on the work of Seymour and Hewitt (among others) to determine the specific effects of learning environments on student attrition. They found that student intentions are malleable (i.e., responsive to very specific changes in the environment) and hypothesize that even minimal changes could profoundly affect student retention . . . Vogt [2011] indicates the importance of engineering faculty's awareness of the value students place on professor-student relationships and encourages faculty to make themselves more personally available" (Meadows, Fowler, and Hildinger 2012). "Good, Rattan, and Dweck (2009) followed several hundred women at an elite university through a semester of a calculus class . . . Women who said that their classrooms promoted a growth mindset were less susceptible to the negative effects of stereotypes, and they were more likely to intend to continue to take math in the future" (cited in Hill, Corbett, and St. Rose 2010).

Antithesis or barrier: Unwelcoming atmosphere from faculty in STEM. *Many students, and particularly members of groups underrepresented in STEM fields, cite an unwelcoming atmosphere from faculty in STEM courses as a reason for their departure (President's Council of Advisors on Science and Technology (PCAST) 2012). "Women who reported that their classrooms communicated a fixed mindset and that negative stereotypes were widespread showed an eroding sense that they belonged in math during the semester, and they were less likely to express a desire to take math in the future" (Hill, Corbett, and St. Rose 2010).*

A community of support

"Research suggests that persistence in college is related to a student's ability to build academic and social connections within their institution" (*Tinto 1987, 1993; Pascarella and Terenzini 1991; cited in Anderson and Kim 2006). "Students typically build these connections by becoming involved in campus organizations or study groups, and from contact with professors outside the classroom" (Anderson and Kim 2006). "Peer influence has . . . been shown to inspire students' decisions to major in a STEM field. Astin and Astin (1992) found that the most consistent environmental influence on a student's choice of major is the number of friends and peers that students possess or knew that were seeking a degree in that field of study" (Crisp and Nora 2006).

Do it: The **Minorities Striving and Pursuing Higher Degrees of Success in Earth System Science® Professional Development Program (MS PHD'S PDP)** "provides professional development and mentoring experiences that facilitate the advancement of persons of color committed to achieving outstanding Earth system science (ESS) careers. The three MS PHD'S PDP phases are connected by virtual community-building activities that occur through asynchronous and synchronous web-based dialogues . . . Informal and formal student interviews and focus groups revealed that technology may be an important medium for connecting mentorship and building community to combat the alienation students of color feel in predominately white academic environments. The MS PHD'S PDP case illustrates how virtual community building strategies help overcome these obstacles and promote peer to peer and peer to protégé mentoring possibilities." (Pyrtle, Powell, and Williamson Whitney 2007)

Antithesis or barrier: Isolation. *The problem of being 'the only, the lonely'. A lack of faculty mentors, peer mentors, and social support programs to combat isolation (George et al. 2001; National Research Council 2011). "[S]everal factors contribute to the low success rates of people with disabilities in post secondary programs and careers in engineering, science and technology" including isolation, low expectations and lack of encouragement (Burgstahler and Cronheim 2001, cited in Pyrtle, Powell, and Williamson Whitney 2007). First generation college students may feel like outsiders in the university community: they are less likely to be integrated into the university because they are "less likely to live on campus, be involved in campus organizations, meet or pursue their most important friendships on campus, or work on campus" (Billson and Terry 1982, 73).*

After school and summer learning opportunities

"The Afterschool Alliance (2011) found in a recent evaluation report of STEM programs across the U.S. that **attending high quality STEM afterschool programs for middle school youth yields STEM-specific benefits** that can be organized under three broad categories (a) improved attitudes toward STEM fields and careers, (b) increased STEM knowledge and skills, and (c) higher likelihood of graduating and pursuing a STEM career" (Howard-Brown and Martinez 2013, bold added).

Antithesis or barrier*: Disadvantaged primary school children's* ***lack of access to out-of-school resources during the summer*** *can result in a 'summer setback' that, despite the equalizing effect of school during the school year, creates an achievement gap between disadvantaged students and advantaged students. Studies found little (or no) school-year differentiation of achievement gains by race or family socioeconomic level in Baltimore primary school children; but identified seasonal patterning of disparities in achievement in reading and math, determining that practically the entire gap evidenced in reading and math between primary students traced to summer learning differentials across family socioeconomic lines. During the summer, upper socioeconomic children's skills continued to advance (albeit at a slower rate than during the school year), but lower socioeconomic children's gains were, on average, flat. (Alexander, Entwisle, and Olson 2001)*

Bridge programs

Bridge Programs help participants prepare for and transition into the next level of their education or stage of career. **For example**: Bridge programs that provide authentic STEM experiences for community college students on a four-year campus allow participants to develop relations with faculty and the campus community and ease the potential transition from a 2- to 4-year institution. Bridge programs supported by private industry and foundations between high schools and colleges or between 2- and 4-year institutions can incorporate learning standards and content consistent with industry-recognized skills (President's Council of Advisors on Science and Technology (PCAST) 2012).

Do it: The **Fisk-Vanderbilt Masters-to-PhD Bridge** program models an effective partnership between primarily white institutions (PWIs) and minority-serving institutions (MSIs) toward significantly broadening the participation of underrepresented groups in the physical sciences: "The program couples targeted recruitment with active retention strategies, and is built upon a clearly defined structure that is flexible enough to address individual student needs while maintaining clearly communicated baseline standards for student performance. A key precept of the program's philosophy is to eliminate passivity in student mentoring; students are deliberately groomed to successfully transition into the PhD program through active involvement in research experiences with future PhD advisers, coursework that demonstrates competency in core PhD subject areas, and frequent interactions with joint mentoring committees. This approach allows student progress and performance to be monitored and evaluated in a more holistic manner than usually afforded by limited metrics such as standardized tests. Since its inception in 2004, the program has attracted a total of 35 students, 32 of them underrepresented minorities, 60% female, with a retention rate of 91%." (Stassun, Burger, and Lange 2010)

Do it: The **Meyerhoff Summer Bridge** program "provides minority students with science, math, and humanities coursework, extensive summer research experiences, mentors from professional and academic STEM fields, merit scholarship support and advocates the use of university student services." (Hrabowski 2003)

Professional development programs or experiences

Professional development experiences give students the skills they need to advance and persist.

Do it: The **Minorities in Marine Science Undergraduate Program (MIMSUP)** "introduces underrepresented students to the marine sciences, helps them develop greater confidence in their potential, and prepares them for successful careers in [the] field . . . Most incoming program participants have limited experience in the marine sciences, in working intensively in the relatively informal environment of a marine laboratory, and in the methodology of research. Furthermore, the students typically represent a wide range of backgrounds, cultures, and academic experiences . . . One of our workshops, while not focused on instrumentation or technology, is extremely important to the students' future success. Shortly after their arrival, the students meet with a career placement professional who instructs them on resumes and curriculum vitae, interview skills, professional letter writing, and graduate school applications. The students subsequently apply these skills in applying for summer internships, fellowships and graduate school positions . . . In teaching these skills, we emphasize graduate school and application strategies. Feedback from the students indicates that this information is extremely useful in 1) getting them to think about graduate school and 2) helping them know how to apply." (Bingham et al. 2003)

Financial aid or other financial support

"White, African American and Hispanic students who attended full-time were more likely to have earned a bachelor's degree within six years of entry" (Anderson 14 2006). Financial aid and appropriate advising can enable students to enroll full-time and reduce their need to work more than 14 hours per week. "[The availability of a range of financial support options, tailored to the needs of students at a particular point in their graduate studies, can be the most effective way to increase recruitment and reduce attrition of underrepresented minority graduate students in STEM" (National Research Council 2011). The National Action Council for Minorities in Engineering rated the availability of adequate financial resources as one of the top five factors related to the persistence of minority engineering students (cited in

Antitheses or barrier: the combination of part-time attendance and working more than 15 hours a week *not only increases time-to-degree, but also increases a student's chance of dropping out (King 2002).*

Landis 1985). Paid traineeships and research assistantships "can expose more underrepresented minority students to teaching and research experiences and provide opportunities for acquisition of scientific skill, professional development, and social integration into a student's program or department" (National Research Council 2011).

*Indicates source citations to be located.

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