Learner Diversity in Earth System Science

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BACKGROUND

NOAA education projects serve individuals across the life span, and exist within a wide range of venues including K-12 classrooms, Higher Education Institutions, and Informal Education Environments (e.g., museums, science centers, nature reserves). These projects focus on NOAA science education in scientific fields related to the agency's mission (e.g., Ocean, Atmospheric, Climate, and Environmental Science). The population of scientists within these fields has been noted as having acute lack (of) individuals from minority populations and women. However, women have recently begun to be recruited and retained at higher rates in all educational levels. Still post-graduate and early career attrition remains an issue.

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The National Research Council (NRC) has convened a committee of 15 experts to review NOAA's education program portfolio and strategic plan (NOAA, 2008).

The minority and female workforce recruitment and retention problems of concern to NOAA are common to most science, technology, engineering, and mathematics (STEM) fields in the United States. Unequal learning opportunities, social and cultural constraints, lack of role models, and negative stereotypes of STEM students and professionals contribute to the differential loss of females and underrepresented minorities from this pipeline during the pre-K-12 years. Selective recruiting, lack of peer support, social bias, lack of fiscal resources, and lack of peer support contribute to this loss after high school.

The magnitude of these problems is greater for the geosciences (including atmospheric and oceanographic) than it is for other STEM fields (Huntoon & Lee, 2007). With this in mind, NOAA's Office of Education has requested the National Research Council to convene a committee of 15 experts to review all of NOAA's education programs. To assist the committee, a literature review and synthesis was requested to address the following five questions:

1. Despite several well intentioned past and ongoing efforts, the geosciences (including atmospheric and oceanic) have not been as effective as other scientific disciplines when it comes to recruiting and retaining students from under-represented groups - why? Are there specific or unique barriers or hurdles or cultural components of these fields that contribute to this lack of diverse participation?

2. What are the hurdles that individuals from minority or under-represented populations face in becoming scientists in these fields?
3. Do different groups face different hurdles (e.g., Latino and Hispanics compared to African Americans compared to Native Americans)? Are these hurdles different in K-12, higher education, or in the professional world?
4. What strategies have been effective in supporting minority and under-represented populations?
5. Are the same strategies effective for all, or are specific strategies appropriate for specific groups of people (within age groups or cultural groups)? Do these strategies differ by venue (K-12, Secondary/Post Secondary, or Informal), or are there common characteristics of effective strategies across these venues?

Given these questions, this review focuses on diversity programs and efforts to broaden participation by people from underrepresented groups in the geosciences (including atmospheric, oceanographic, and environmental sciences). Since the problems faced by the geosciences and the etiology of these problems share commonalities with STEM in general, we have reviewed the literature on interventions intended to broaden the participation of people from underrepresented groups in STEM as well as the specific disciplines that are of special interest to NOAA.

For this review, we have developed a simple model for categorizing the different types of diversity efforts that are being employed. This model dichotomizes interventions with respect to their basic underlying goals:

(1) Leveling the playing field.*This refers to interventions whose objective is the reduction or elimination of gaps between people from underrespresented groups and others with respect to the knowledge, abilities, and skills that are essential for success in a STEM career*.

(2) Attracting students to a specific discipline.*This refers to interventions whose objective is the creation and/or maintenance of interest in a career in a specific discipline.*

The theoretical underpinnings of the first approach ("Leveling the playing field") reflects the belief that many people from underrepresented group's educational and socio-cultural background fail to provide the experiences and training that are crucial for success in STEM careers. Such individuals do not succeed in STEM because, in general, they are not as well prepared academically for the rigors of STEM (Seymour & Hewitt, 1997). For example, 22 percent of the nation's public secondary school math courses are taught by teachers with neither state certification nor an academic major in mathematics or a mathematics related subject (such as physics, engineering, or math education). However, in high poverty secondary schools, 41 percent of the mathematics classes are taught by out-of-field teachers; in high minority schools, 30 percent are taught by out-of-field teachers (Education Trust, November 2008). So, interventions intended to enable high-quality and effective instruction in mathematics and the sciences, as well as interventions intended to provide people from underrepresented groups with study and social skills possessed by mainstream students have been developed and implemented, in attempts to level the playing field. Interventions intended to counter the impacts of stereotype threat -- the underperformance of groups whose abilities are negatively stereotyped by the broader society (Steele, Spencer, & Aronson, 2002) and to enhance students' sense of STEM self-efficacy (including exposure to role models that are more likely to be part of other students' life experiences) are also intended to level the playing field. Interventions intended to level the playing field typically focus on factors that are common to STEM in general, rather than factors that are relevant for a specific discipline.

The second approach ("Attracting students to a specific discipline") refers to interventions that provide experiences which are intended to attract students to a specific field. The experiences that are provided by such interventions are those to which students are not typically exposed, with the underlying intent of creating or sustaining an interest in a discipline. Research experiences, internships, field trips, and informal education programs are examples of this approach. This approach is rarely employed with graduate students (for whom a discipline-specific commitment is assumed). Rigorous evaluation of the long-term impacts of program components using this approach are rare, due to the logistical difficulties associated with long-term follow-up needed to conduct such research.

Even though many programs have components that try to address both goals, a typical intervention component usually addresses only one. Since there appear to be associations between evaluation strategies, evidence of success, and the types of individuals (particularly with respect to grade/education level) to whom each approach is targeted, we feel this perspective can help the committee in the development of its recommendations.

We would also like to note that evaluations of diversity interventions rarely, if ever, focus on the question: What aspect of this intervention is responsible for its success (with members of a specific underrepresented group)? Although formative evaluation efforts often focus on specific program components, the summative evaluation components look at project (rather than component) impacts. For example, the efficacy of mentoring programs has been clearly demonstrated. However, the specific attributes of a mentoring experience that promote its effectiveness (either in general or for a specific type of student) remain to be demonstrated. Their systematic investigation could inform program revision.

An example of our lack of knowledge of the specific components of an approach that make it effective is provided by Borman, Gamoran, and Bowdon's (2008) recent evaluation of a professional development program intended to enhance content knowledge and improve the abilities of Los Angeles elementary school teachers to provide hands-on science instruction to their students. It should be noted that the approaches employed in this research – providing professional development to teachers that is linked to curriculum, providing subject matter knowledge, and providing knowledge about how students learn the subject rather than focusing only on teaching behaviors have been shown to be a superior approach. Similarly, presenting science curricula based on the inquiry approach has been shown to be more effective than traditional science curricula (Clewell, Cohen, Deterding, Mays, & Tsui, 2005). In this randomized, controlled trial, these best practices resulted in a statistically significant negative impact on students' science test scores after their teachers participated in this seemingly well-designed, intensive professional development program, based on proven principles. The impact was worse for the more experienced teachers. The decrement for newer teachers, although negative, was not statistically significant. In other words, even if an intervention approach is based on sound principles, the way that it is implemented can have profound effects on its efficacy.

Barriers for underrepresented minorities do not disappear with the acquisition of a college degree. Workplace barriers contribute to further pipeline loss after graduation (BEST, 2004). At institutions of higher education, isolation and lack of mentoring, occupational stress, devaluation of minority research, the "token hire" misconception, racial and ethnic bias in recruiting and hiring, and racial and ethnic bias in tenure and promotion practices and policies all operate to hinder the recruitment and retention of faculty of color (Turner, Myers, & Creswell, 1999).

The following sections address the five specific questions deemed to be the focus of this review.

- "Characteristics of the Geosciences that may hinder participation of people from underrepresented groups" addresses research question 1 [*Despite several well intentioned past and ongoing efforts, the geosciences (including atmospheric and oceanic) have not been as effective as other scientific disciplines when it comes to recruiting and retaining students from under-represented groups - why? Are there specific or unique barriers or hurdles or cultural components of these fields that contribute to this lack of diverse participation?*].

- "Hurdles" addresses research questions 2 (*What are the hurdles that individuals from minority or under-represented populations face in becoming scientists in these fields?)* and 3 [*Do different groups face different hurdles (e.g., Latino and Hispanics compared to*

African Americans compared to Native Americans? Are these hurdles different in K-12, higher education, or in the professional world?].

- "Strategies" addresses research questions 4 (*What strategies have been effective in supporting minority and under-represented populations?*) and 5 [*Are the same strategies effective for all, or are specific strategies appropriate for specific groups of people (within age groups or cultural groups)? Do these strategies differ by venue (K-12, Secondary/Post Secondary, or Informal), or are there common characteristics of effective strategies across these venues?*].

These sections are followed by a summary and general conclusions.

CHARACTERISTICS OF THE GEOSCIENCES THAT MAY HINDER PARTICIPATION OF PEOPLE FROM UNDERREPRESENTED GROUPS

Characteristics of the geosciences that distinguish them from other STEM disciplines may contribute to underrepresentation of certain groups of people. In the following section we describe some of these characteristics such as small size, lack of awareness of the geosciences, and exposure to the outdoors. It is worth noting that these characteristics may overlap with some of the hurdles discussed in the next section and themselves may be related (e.g., small size and lack of awareness of the geosciences).

Small size

The Division of Science Resource Statistics (SRS) at NSF and the U.S. Department of Education's National Center for Education Statistics (NCES) tabulate the numbers and types of college degrees awarded in STEM fields. From 1966 – 2001, the geosciences was the science or engineering field with the fewest number of degree recipients (at each of the bachelors, masters, and doctoral levels) (Huntoon & Lee, 2007). The fact that the smallest STEM field is the STEM field with one of the most serious underrepresentation problems may not be coincidental.

Small numbers of geoscience graduates means that, compared to other fields, students and their families will have a decreased likelihood of knowing or interacting with anyone with a geoscience degree. Since neighborhoods and social groups tend to be socioeconomically stratified, people of lower socioeconomic status (who are disproportionately from underrepresented groups) are less likely to know any STEM professionals than members of the general public. So, a lack of awareness of the geosciences and a lack of knowledge about geosciences careers is likely to typify the parents and families of people from underrepresented groups in urban areas. Parents encouraging their children to go into lucrative fields (medicine and law) with which they are familiar rather than occupations that they know little or nothing about (i.e., the geosciences) is a factor in the major choice of some individuals from underrepresented groups (Bembry, Walrath, Pegues, & Brown, 2000).

At a bare minimum, this decreases the likelihood of a geoscientist serving as a role model, compared with any other STEM professional. Since role models have been cited as a factor associated with STEM career entry (Office of Technology Assessment, 1988), it appears that size may matter. In our recent review of the literature and critical incident study (Levine, González, Cole, Furhman, & LeFloch, 2007), we were unable to find any examples of minority role models influencing geoscience career choice. We speculated that this was due to the dearth of minority geoscientists.

Small size can also contribute to academic isolation (discussed in the next section). However, small size has certain advantages. If geosciences diversity programs are having their intended impacts, these effects are more likely to be noted (Karsten, 2003). An increase of 100 people from underrepresented groups earning geoscience degrees will have a profound and noticeable effect on the proportion of undergraduate geosciences degrees earned by members of these underrepresented groups; an increase of 100 biology undergraduate degrees would be scarcely noticeable. From 1995 to 2001, the proportion of undergraduate geosciences degrees awarded to students from underrepresented groups increased by 61 percent from 3.9 percent to 6.3 percent[2] -- a proportional increase greater than that observed in other STEM disciplines. We believe it is likely that NSF's geosciences diversity programs have helped contribute to this growth. Over the same time period, the proportion of undergraduate physics degrees awarded to students from underrepresented groups increased by 16 percent, from 7.6 percent to 8.8 percent (NSF, 2007).

Awareness of geoscience

Other barriers to recruitment and retention for the geosciences are availability, perception, and knowledge of geoscience courses (Levine et al., 2007). In high school, the geosciences are not as widely taught as biology, chemistry, or physics. The College Board does

[2] This is an increase of about 100 graduates.

not even offer an Advanced Placement Geoscience course (College Board, 2009). And, as our critical incident study showed, they are not considered to be a rigorous pre-college science course (Levine et al., 2007). According to State Indicators of Science and Mathematics Education, 28 percent of high school students take a high-school earth science course, while approximately 95 percent of high school students take biology (Blank & Langesen, 2005).

In our critical incident study, we found some students were recruited into the major simply by exposure to the discipline. Several critical incidents were collected on students who entered the geosciences after enrolling in an introductory geoscience course. Some of these incidents described students who were unaware of the discipline, enrolled in an introductory geoscience course, enjoyed the course, and ultimately became geoscience majors. The reasons for enrolling in an introductory geoscience course included an interesting description in the course catalogue, wanting to explore different science fields, and having a professor encourage enrollment (Levine et al., 2007).

At community colleges and at Minority Serving Institutions of Higher Education (MSIs), students from underrepresented groups are proportionally overrepresented (Provasnik & Planty, 2008). These types of schools are less likely to offer geosciences courses than other institutions of higher education (Lopez, 2009), exacerbating the impact of lack of awareness of the fields of geoscience.

Outdoor education/experiences

Outdoor experiences are a factor that attracts individuals to the geosciences (Levine et al., 2007). It is not surprising to most geoscientists that a love of the outdoors was cited as motivation to enter the geosciences. Outdoor experiences that can help foster an appreciation for nature were identified by several geoscientists as a factor associated with their geosciences major and career choice. Since many people from underrepresented groups live in urban areas, their exposure to outdoor experiences and outdoor education is almost certainly less than that experienced by non-urban students. In a study recently completed for the Sierra Club, outdoor education experiences appeared to be especially beneficial to English Learner (that is, Hispanic/Latino) sixth grade students, promoting acquisition of a number of social and personal skills which appear to be important for academic success (American Institutes for Research, 2005). In these ways, outdoor experiences can promote retention in a geosciences career pipeline.

Different outdoor experiences may attract students to specific disciplines within the geosciences. Most aquatic scientists develop an affinity for water as children, resulting from exposure to lakes, creeks, and/or the oceans. Some people from underrepresented groups, raised in inner cities and who do not have a culture of going to the beach, are not provided with as many opportunities for this exposure. Additionally, some people from underrepresented groups with the interest and ability to pursue aquatic science careers are often directed to pursue medical careers, due to a lack of role models for non-medical science pursuits (Cuker, 2001). To provide exposure to aquatic science, programs were developed at minority serving institutions (MSIs), such as the Minorities at Sea Together (MAST) Program at Hampton University. This month-long summer program provides exposure to aquatic science and the ocean in a setting that also includes a critical mass of minority students, mentors (who also serve as role models), hands-on research experiences, and compensation.

Interventions providing outdoor experiences can also be structured to promote geoscience career choice and retention in the individuals associated with providing the intervention services. Science majors at a Historically Black College and University (HBCU), who received training in natural history pedagogy, provided marine science camp experiences and/or geosciences lessons to school children. This resulted in an increase in the number of participating students who chose to go into science teaching (Pride & Olsen, 2007).

Field experiences for high school students, combined with mentoring and financial support for those who choose to attend college as geoscience majors, has been used as a strategy for promoting diversity in the geosciences by the University of New Orleans for over thirty years (Serpa, White, & Pavlis, 2007). These outdoor experiences, by providing people from underrepresented groups with opportunities that are generally lacking, can help to level the playing field in a way that can also attract students to the oceanic and geosciences.

Although outdoor experiences appear to promote retention in a geoscience career pipeline, exposure to the outdoors and opportunities to work outdoors are almost certainly not of comparable importance for people from certain underrepresented groups. Among rural Alaska natives, working outdoors is associated with subsistence hunting and non-professional employment activities. One of the attractions of a geoscience career is the opportunity to work indoors, at a desk job (Hanks, Levine, Wartes, & González, 2005).

Characteristics of the Geosciences that many hinder participation of people from underrepresented groups summary

The lack of geoscience course offerings in K-12 schools (relative to other STEM class offerings) means that students in general will be less aware of the geosciences. This problem is exacerbated for African-American and Hispanic students by the comparative lack of geosciences course offerings at MSIs and at community colleges, where minorities are proportionally overrepresented.

The small numbers of individuals graduating with degrees in the geosciences (relative to those graduating with degrees in other STEM fields, such as biology) reduces the likelihood that any student will learn about the geosciences through contact with a family member or family friend who is a geoscientist. For minority K-12 students, this problem is intensified by the underrepresentation of minorities in the geosciences and by racial and ethnic residential segregation in the United States (Iceland, Weinberg, & Steinmetz, 2002).

African Americans and Hispanics are proportionally overrepresented in inner cities (American Community Survey, 2007; Therrien & Ramirez, 2001). Living in urban, inner-cities decreases a student's opportunities for exposure to nature and the outdoors (compared to students living elsewhere). Since an appreciation of the outdoors and outdoor experiences are a characteristic of those who pursue geosciences careers, the reduced opportunities for outdoor experiences further increases the problem of underrepresentation of minorities in the geosciences.

HURDLES

According to Chapa and De La Rosa (2006), “The educational ‘pipeline’ for Latinos is rife with massive leaks. The ultimate result is that graduate degree recipients from the nation’s colleges and universities do not reflect the racial and ethnic diversity of the population... In 2000, Latino individuals accounted for 12.5% of the total population and 17.5% of the college-age population; however, only 10.8% of the high school graduates were Latino, 9.9% of the associate degree recipients were Latino, and only 6.6% of all bachelor’s degrees and 3.8% of all doctorates were Latino individuals.”

As people from underrepresented groups progress through the educational system, they face a variety of obstacles. Factors such as culture, life experiences, quality of schooling, and exposure to the STEM careers can serve as elements to either attract or discourage students from pursuing advanced degrees in these fields. This section examines some of the hurdles that people from underrepresented groups must overcome and that institutions must address in order to effectively diversify academic settings.

Racism and negative stereotypes

Negative perceptions of academic environments and lower levels of cultural congruity can emerge from a variety of contextual issues, such as encounters with discrimination and hostile learning environments. A survey of earth science teachers in New Jersey indicated that over 95 percent of the respondents were White. Analysis of open-ended responses indicated that

20 percent displayed feelings of cultural or racial bias towards minorities. Thirty percent did not perceive a need to encourage minority students to pursue STEM careers (Zappo, 1998). Ultimately, these experiences can lead students from underrepresented groups to experience lower levels of cultural congruity and negative perceptions of academic environments (Gloria, Castellanos, Lopez, & Rosales, 2005; Gloria, Hird, & Navarro, 2001).

The literature suggests that students from underrepresented groups are susceptible to negative stereotyping from their peers (Steele, 1997; Taylor & Antony, 2000). Stereotype threat is a psychological predicament in which people fear being evaluated in terms of a negative stereotype about a group to which they belong. As a result, stereotype threat may create anxiety and self-doubt, lowering performance in relevant domains. Stereotype threat may have a long-lasting effect on school achievement by “preventing or breaking a person's identification with school, in particular, those domains of schooling in which the stereotype applies”[3] (Steele, 1997).

A critical incident study of high-achieving Black and Latino undergraduates indicated the presence of beliefs of inferiority. That is, students saw themselves as being less talented in STEM, leading to choice of other majors to avoid being below average in their major fields (Brown & Clewell, 1998). In another critical incident study, African-American student overheard negative comments from classmates about her internship, attributing its award to the student’s race (Levine et al., 2007). One respondent reported that one of her classmates told her that she only had her internship because she was a minority. She heard similar “cheap shots” from other students as well. She reported that at the time, she was struggling with her own confidence and

[3] Recent work by Cohen, Garcia, Apfel, and Master (2006) suggests that simple interventions to enhance student’s self of personal adequacy can be very effective in ameliorating the impacts of stereotype threat.

ability in the field and these comments did not help. Experiences with racism and negative stereotypes, in addition to ethnic isolation, often due to a lack of critical mass, makes it harder for students to deal with the effects of racism.

The same "cheap shots" were reported by graduate African-American students during interviews we conducted as part of technical assistance site visits in 2005. These graduate students expressed gratitude for the fact that there were other graduate students from underrepresented groups with whom they could discuss such issues. Students are in greater danger of transferring out of STEM when they internalize negative stereotypes. One example provided by Seymour and Hewitt (1997) captures the experiences of some students of color:

> I know a black woman who switched to art, she was going to be a physics major. Her physics professor came and told her, 'Why are you in my classroom. What you can possibly want to know about physics?' And it was horrible for her…and, coming from a professor, you know, that is devastating for a student (p. 358).

Stereotype threat and negative experiences with racism does not stop for people of color after college or graduate school. Faculty of color also may have negative experiences that may impact their retention in the professoriate. Analyses of the U.S. Department of Education's 1999 National Survey of Postsecondary Faculty showed that, controlling for other factors, Latino faculty were less satisfied than White faculty with respect to their job duties. In addition, both Latino and African-American faculty were likely to agree that the institutional climate was less fair for faculty of color than White faculty (Ponjuan, 2006). In addition, the literature suggests that that people of color are judged on different criteria from their White counterparts (e.g., Konrad & Pfeffer, 1991; Turner & Myers, 2000).

Cultural barriers

Differences in ethnic cultural values and socialization are an important reason why students from underrepresented groups are not retained in STEM (Fiske, 1998; NSF, 1996; Seymour & Hewitt, 1997). For example, children of immigrants run into cultural barriers, with parents discouraging or prohibiting their children to go away to summer camps or to participate in evening study groups.

Native Americans and Latinos possess strong cultural values of group and community membership that are often at odds with the levels of individualism and competition associated with the sciences (NSF, 1996). A study by Seymour and Hewitt (1997) found that an obligation to serve the community, the conflict between academic and family responsibilities, cultural restraints on self-assertiveness, and cultural variations in peer group success norms were various ethnic and cultural values unique to certain underrepresented groups. A variety of cultural aspects affect Hispanic college students as they continuously struggle to balance participation in their home and academic cultures. One of the important assets of the Hispanic culture is the close family relationships that it fosters; however, these ties also play a crucial role in the decisions that students make about pursuing a college education (Fiske, 1998). For example, many students report that it is “hard to break away” to attend college far from their families. In some instances, parents are opposed to letting their kids move away to attend college.

Cultural expectations can lead to education receiving a lower priority in some people from underrepresented groups than in the mainstream culture. For example, Hispanics are more likely than Whites to feel obligated to provide services and support to their families during their college years (Seymour & Hewitt, 1997). This can reduce the amounts of time and energy that are devoted to the educational activities that are essential for geosciences careers. Hispanic students are more willing than other students in similar economic circumstances to change or delay their academic plans so that they can help earn money for their family (Fiske, 1998).

Cultural incongruity that may arise between people from underrepresented groups and the dominant culture can increase barriers to students' social and academic integration. This adds an additional challenge and consideration for retention. The literature suggests that in order for geologic research to remain relevant to indigenous communities and societies, it is essential to validate indigenous cultural knowledge systems and to integrate indigenous methodologies in research processes. Louis (2007) defines indigenous methodologies as "fluid and dynamic approaches that emphasize circular and cyclical perspectives." The main goal of indigenous methodologies is to conduct research in more sympathetic, respectful, and ethically correct ways from an indigenous perspective. Research courses can be intimidating because the methodologies tend to privilege linearly oriented research paradigms and as a result indigenous students can feel alienated and isolated. So, Kovach (2005) recommends the integration of indigenous methodologies into general research courses not simply as an ad hoc aspect, but as an integral component of the curriculum.

Academic isolation

With the small number of people from underrepresented groups in STEM, academic isolation is likely to arise. Academic isolation for students from underrepresented groups can be dealt with by offering geosciences courses and degree granting programs at minority serving institutions (MSIs). These include the Historically Black Colleges and Universities (HBCUs), the Tribal Colleges and Universities (TCUs), as well as colleges and universities classified as being Hispanic Serving Institutions (HSIs). In 2004, about half of the physics B.S. degrees earned by African Americans were earned at HBCUs. Conversely, only about 12 percent of the geoscience B.S. degrees earned by African Americans were earned at HBCUs. This reflects the fact that few HBCUs (or HSIs or TCUs) offer geosciences degrees (Williams, Morris, & Furman, 2007).

Data suggest that as the numbers of Latino students and faculty on campus increase to a critical mass, academic success increases as well. Hagedorn, Chi, Cepeda, and McLain (2007) examined the effect of the level of representation of Latino students and faculty on the academic success of Hispanic or Latino urban community college students and found a positive relationship with student success and enrollment in transfer/non-remedial courses, and a negative relationship with enrollment in remedial/pre-collegiate English and math courses. Their findings also indicate that the presence of Latino faculty on campus may increase the availability of role models for students and foster a sense of belonging and social integration among students.

Even at the faculty level, academic isolation for faculty from underrepresented groups is an issue. According to the National Center for Education Statistics (2008), in 2005, people from underrepresented groups comprised only 9.2 percent of full-time faculty in the U.S. (5.3 percent

Black, 3.4 percent Hispanic, and 0.5 percent American Indian/Alaska Native). Of these, only 5.8 percent were full professors (3.2 percent Black, 2.2 percent Hispanic, and 0.3 percent American Indian/Alaska Native). Turner, González, and Wood's (2008) literature review and synthesis of 252 publications addressing the status and experience of faculty of color emphasized institutional barriers to the recruitment and retention of faculty from underrepresented groups and developed recommendations for dealing with isolation and other barriers.

General academic preparedness

The selection and persistence of students from underrepresented groups in STEM majors has been significantly associated with their academic preparation in high school (Elliot, Strenta, Adair, Matier, & Scott, 1996). Anderson and Kim (2006) reported that students who earned a Bachelor's degree in STEM fields were better prepared for college if they took a "highly rigorous high school curriculum." As previously noted, the prevalence of out-of-field mathematics instruction (that is, mathematics instruction by teachers who are neither certified to provide instruction in the field nor who majored in mathematics or a mathematics related discipline) is substantially higher in high poverty and high minority high schools (Education Trust, 2008). These schools are also less likely to offer Advanced Placement (AP) courses; gaps between students from underrepresented groups' and white students' participation in Advanced Placement continue to be documented (Klopfenstein, 2004).

Enrolling in high school STEM classes can prepare minority students for rigorous STEM coursework in college. An NSF report (1996) showed that only 1.2 percent of Latinos students took algebra II, geometry, and trigonometry in their high school programs (and only 0.9 percent took calculus). Without a strong academic preparation in STEM in high school, minority students are less likely to remain in a STEM pipeline. Indeed, much of the literature on minority students in STEM stresses the importance of academic preparation of these students (Bembry et al., 2000; Chang, 2002; Committee on Equal Opportunities in Science and Engineering, 2004; Feuers, 1990; Grandy, 1998; NSF, 1994; Seymour & Hewitt, 1997; Strenta et al., 1994; Brown, 2002; Wilson, 2000). Strategies to level the playing field are critical for overcoming such gaps.

The loss of undergraduate students in different STEM majors is quite high. About 40 percent of undergraduates leave engineering majors; 50 percent leave biological and physical science majors, and 60 percent leave mathematics majors. These numbers are disproportionately higher for females and minority students (Seymour & Hewitt, 1997; Smith & Hausafus, 1998). We found evidence of this in our critical incident study (Levine et al. 2007). Some of this attrition is clearly related to the daunting challenge of mathematics courses for students lacking a rigorous mathematics background. It is particularly frustrating for students who did well in less rigorous science and mathematics courses in high school, but who subsequently cannot meet the challenges of college mathematics and science courses (Bembry et al., 2000; Brown & Clewell, 1998). Students who were unable to satisfy the mathematics requirements of geoscience majors reported this as an important reason for switching majors (Levine et al., 2007).

Lack of familiarity with STEM careers

Knowledge of STEM careers has been shown to influence minority students' career choices. In a study conducted by Brown and Clewell (1998), several students commented on their ignorance of STEM careers: They would have considered a STEM career if they had known more about such careers. A lack of knowledge hinders minority participation in STEM fields in other ways.

STEM internships can promote retention in the geoscience pipeline. The importance of positive internship experiences in the geosciences was validated in a critical incident study (Levine et al., 2007). Numerous incidents described how internships allowed students to learn more about the field, provided them with practical experience, and built one student's confidence. Brown and Clewell (1998) pointed out that the quality of internships is also important, as some minority students left the STEM pipeline due to negative summer internship experiences. (Most of the negative internship experiences were in engineering.[4])

Lack of familiarity with higher education

Many students from underrepresented groups are the first in their family to attend college. This lack of familial information about the college environment and culture may result in unrealistic expectations about academic and other aspects of the college experience. The college (and graduate school) application process is not intuitive. Additionally, students from underrepresented groups are often unaware of the financial support available to assist them.

Perceptions of ability and self-efficacy

Students' perceptions of their own ability and a willingness to defer gratification can also impact underrepresented students' decisions to remain in or to leave the pipeline. STEM courses often have the "stigma" of being academically rigorous. Brown and Clewell (1998) found that

[4] This is another example of the importance of learning the components of interventions that are responsible for their success.

the course requirements, the intense competitiveness among students in STEM courses, the restrictive curriculum of STEM majors, and the time demands of STEM courses were reasons that minority students avoided STEM majors. Although difficulty in STEM courses affected retention in STEM majors, an equally important component of STEM retention was minority students' "perceptions of their ability to be successful in a STEM major." These minority students reported they could not handle the workload for STEM majors, often leading to self-defeating behaviors. Students who believed they were well prepared from high school or accepted the challenge of the workload were less likely to switch out of STEM majors (Bembry et al., 2000).

Financial stress

Numerous researchers have written on the important role that finances play in the retention of students of color (Carter, 2006; Hu & St. John, 2001; Seidman, 2005). Not surprisingly, scholars have shown the importance of finances for students from underrepresented groups in STEM (CAWSMET, 2000; Georges, 2000; Quimbita, 1991). Studies often conclude that grants or scholarships are more beneficial in retaining students from underrepresented groups than loans (Fenske, Porte, & DuBrock, 2000). Seidman (2005) also argued for providing additional support and knowledge about the financial aid process to students.

Lack of social support from peers and family

Collaborative group work and study groups can enhance student performance and facilitate mastery of challenging constructs. They appear to be particularly beneficial for minority students in fields that initially are perceived as intimidating or unwelcoming (Farrell, 2002). But these groups are less likely to include students from underrepresented groups, particularly when these students' social groups are less likely to include STEM majors and when these social groups have little prior experience with study groups.

Family support can be a critical factor in overcoming barriers. In a study of 22 successful Hispanic science and engineering students, all of the 22 students had support systems that enhanced their development and education. Even though six of these students were raised in single-parent, low-income families, supportive and involved mothers (in addition to supportive grandparents) provided an environment in which education and the pursuit of knowledge was encouraged (Brown, 2002). It is also noteworthy that 19 of these students were in honors high school programs, and tracked with students with comparably high abilities.

Hurdles summary

This section discussed the following salient hurdles that must be addressed in order to diversify the STEM workforce: racism and negative stereotypes, cultural barriers, academic isolation, poor academic preparedness, lack of familiarity with STEM careers and higher education, negative perceptions of ability and self-efficacy, financial stress, and lack of social support from peers and family.

Susceptibility to racism and stereotypes may cause students from underrepresented groups to experience lower levels of cultural congruity and to develop negative perceptions of academic environments. As they try to balance academic and family commitments, their decisions are influenced by their cultural values and expectations. Consequently, cultural incongruity may discourage students from going into or remaining in the STEM pipeline.

Given the small numbers of people from underrepresented groups in the STEM fields, academic isolation is a salient predicament for minority students and faculty. Accordingly, the literature suggests that increasing the number of people of color in academia, thereby creating a critical mass, is essential for fostering the social integration and academic success of students from underrepresented groups.

A crucial factor in postsecondary success is the academic quality and intensity of the high school curriculum (Adelman, 2006). Thus, limitations on the general academic preparation of students from underrepresented groups, principally in mathematics and science, represent a key hurdle in meeting the demands of STEM careers. Furthermore, their success may be restricted by their lack of familiarity with the demands of a higher education and STEM careers, as well as self-defeating behaviors related to negative perceptions of ability and self-efficacy.

In addition, financial stress is a key element in deterring students from underrepresented groups from higher education and academic careers. Therefore, it is critical to provide information about the financial aid process and the different options for funding a higher education, especially through grants or scholarships, since these have been particularly effective in the retention of students from underrepresented groups.

In light of the aforementioned factors, it is important to consider how family and peer support may serve as key social and cultural capital in the development of effective strategies for people from underrepresented groups to prevail in the STEM pipeline.

STRATEGIES

Based on the hurdles that people from underrepresented groups face in becoming STEM professionals, programs have responded by attempting to address these various hurdles. While many programs exist, there are numerous challenges associated with identifying effective programs that seek to increase the number of people from underrepresented groups in STEM. Lack of systematic research on programs makes it harder to determine program impacts. As stated earlier, it is also difficult to tease out the effect of different strategies used by programs to determine which strategies were most effective. The cost of measuring long term impacts and subsequently the lack of studies looking at long term impacts also limits our understanding of program strategies. In addition, we may not even know about some of the most effective programs if such programs are run by people outside of academia who may not have the inclination, time, or skill to write a scholarly article about their program. In 2004, BEST (Building Engineering & Science Talent) sponsored an assessment of best practices to increase the participation of people from underrepresented groups and to increase female participation in STEM. As part of this effort, the research-based evidence for 34 educational interventions intended to better serve underrepresented students in Pre-K-12 mathematics and science was reviewed to identify those programs for which effectiveness had been demonstrated.

The criteria employed by our colleagues at the American Institutes for Research (AIR) in the conduct of this assessment was exceedingly rigorous. None of the interventions' effectiveness was "verified" because none of the interventions met the criterion of "five studies of acceptable rigor, conducted by independent evaluators, showing substantially positive results." Two of the studies met the criterion for "Probable Effectiveness," seven met the criterion for "Notable Effectiveness," and eleven had "descriptive evidence that warrants further research" (BEST, 2004).

The BEST research team identified important principles for designing effective interventions. These were:

- Defined outcomes. Students and staff develop goals and desired outcomes and measure success relative to these outcomes.
- Sustained commitment. Continuity of funding and institutional support are essential.
- Personalization. Teaching is student centered; mentoring, tutoring, and peer interaction are key components of the learning environment.
- Challenging content. Content exceeds minimal standards and is related to real-world applications.
- Engaged adults. Active family support is sought. Educators believe in the potential of all students and serve as mentors, tutors, counselors, and coaches in addition to being teachers.

They also noted that all of the above are necessary for effective interventions.

We reviewed these interventions along with a general literature review, looking for specific strategies that would attract and retain people from underrepresented groups to the geosciences. We also used more liberal criteria, reflecting our belief that it was not necessary to have a program evaluated by five independent evaluators to demonstrate its probable efficacy. All of these interventions employed a variety of different strategies. This made it impossible to assess the relative efficacy of any specific strategy. This lack of focus on mechanisms that are responsible for impacts required us to use our best professional judgment in deciding on the specific program mechanisms that were associated with positive outcomes, to enable us to address the questions of interest to the committee. We are highlighting strategies in several of these interventions because of their relative novelty and/or because of conceptual linkages with elements of our Geoscience Career Pipeline model (Levine et al., 2007). Below we describe several programs that have been created to combat the hurdles, discussed above, that people from underrepresented groups face. Most of these approaches are attempts to level the playing field, providing comparable opportunities for students from underrepresented groups.

Programs that Address Academic Preparedness of Students

Many interventions, in the form of programs designed to serve underrepresented students in Pre-K-12 mathematics and science programs, have been developed and implemented in attempts to level the academic playing field for students from underrepresented groups. These include NSF's Urban Systemic Initiatives and Rural Systemic Initiatives. These are examples of "leveling the playing field" interventions, with the goal of raising the knowledge, skill, and ability levels of American students to levels commensurate with those of students in other nations whose performance exceeds that of the United States in international studies. The value and need for such interventions is clear. Poor teaching in STEM courses, along with a lack of encouragement from teachers and/or parents were shown to be STEM turn-offs for high ability students from underrepresented groups (Brown and Clewell, 1998).

Numerous programs were identified by BEST as using best practices to address academic preparedness of students. As is true of many of the programs described, best practices usually included using a variety of strategies to address hurdles faced by students. Yup'ik Mathematics incorporated a *culturally based curriculum, developed through community input.* It emphasized every day and *practical knowledge* and employed a hands-on approach, resulting in gains in math skills and abilities for rural Alaskan native elementary school students. In contrast, Project GRAD (Graduation Really Achieves Dreams) enlisted the help of *social service agencies to provide support* to high risk students, in addition to incorporating a classroom management program that emphasizes shared student and teacher responsibility for learning. This was rated by BEST as a "Notable" intervention, with substantial increases in college attendance rates for participating students, as well as improvements in math and reading scores. Other programs also provide pre-college supports, and tailored the specific supports provided to students (besides the usual completion of the college application). For example, the Texas Prefreshman Engineering Program (TexPREP) and the University of North Carolina Mathematics and Science Education Network (MSEN) Pre-College Program explicitly included *communications skills training* in the programs. Both reported high college admission and graduation rates, with large numbers of students entering STEM careers (97 percent of the MSEN participants received post-secondary education.)

Most students from underrepresented groups do not participate in these special pre-K-12 programs. When they enroll in post-secondary school, their academic gaps often remain. Accordingly, some universities have created courses and/or programs to help students who are academically at risk succeed in STEM. One HBCU created an academic bridge program for freshmen majoring in science and technology (Payne & Dunsberry, 2007). Students were targeted in the entry level biology, mathematics and chemistry courses. Professors who taught courses provided a Saturday program of study that provided additional supports to students enrolled in the program. Students who received less than a C on the first midterm were required to retake the midterm after considerable review. The university illustrated that students who participated in the program received better grades than those that did not. Another study of a university program to support STEM majors described a pre-engineering and algebra course created by the university for "at risk" students (George & Burden, 2007). The algebra classes were all standardized, a lab was instituted, supplemental computer drills were created, a coordinator for the class was hired, and additional tutoring was provided. Results from this program also illustrated that students who were “at risk” fared better when they participated in the program and enrolled in both the algebra and pre-engineering course together than those students who did not.

The Committee on Equal Opportunities in Science and Engineering (CEOSE), a congressionally mandated advisory committee to NSF, recommended focusing attention on the role of community colleges as a vital pathway for the entry of people from underrepresented groups into STEM (2004). In 1996, NSF reported that more than 35 percent of minorities graduating with B.S. degrees in science and engineering began their post-secondary education at community colleges. A significant proportion of community colleges offer programs to encourage females and minorities to enroll in science and math and to help them succeed in these fields (Quimbita, 1991). Approaches include ensuring that students have the basic skills needed for success in college-level science and math courses; providing social and academic support networks; providing role models; and providing financial support. Banks and Railsback (1988) reported than nearly half of the 91 community colleges they surveyed offered such programs. One-third of the students at community colleges enroll in remedial mathematics courses (National Science Board, 2002).

Programs that Address Career Awareness and Professional Socialization

Exposure to knowledge of career opportunities can also help attract and retain students to specific disciplines, in addition to leveling the playing field by providing experiences that are generally lacking amongst students from underrepresented groups. The Pathways program, at the University of Texas at El Paso, conducts two-week summer outreach sessions for local (predominantly Hispanic) 11^{th} grade students. One of the key components of this program involves teaching these students about career opportunities in the geosciences (Miller et al., 2007). This contributed to positive changes in participants' attitudes about the profession, at least in the short-term.

Some programs, while teaching about career awareness, also provide students with specific skills to help them stay in the geoscience pipeline. Minorities in Marine Science Undergraduate Program (MIMSUP) teaches about graduate schools and the graduate school application process and strategies. Participating students reported this as being invaluable in getting them to think about graduate school and teaching them how to apply. The proximity of graduate students in their labs undoubtedly results in participants learning more about the graduate school application process (Bingham et al., 2003). These opportunities go beyond leveling the playing field and provide knowledge and insights about the graduate school application process that most undergraduates lack.

Some programs address professional socialization and career awareness while attempting to reduce social isolation. They include the activities of professional associations which seek to make students familiar with academia and the behaviors expected of professional researchers as well as introduce them to peers and other scientists of color. The Society for the Advancement of Chicanos and Native Americans in Science (SACNAS) holds an annual conference for students from underrepresented groups. This conference provides opportunities for students to attend a professional meeting and to present their work to their peers. Workshops are held to help students acquire the skills needed for professional development. The American Society for Limnology and Oceanography Minorities Program (ASLO-MP) provides similar opportunities and also assigns "meeting mentors" to students to enhance the experience. Most of the ASLO-MP students earn undergraduate degrees; 36 percent have earned advanced degrees (Cuker, 2005). Similarly, the American Indian Science and Engineering Society (AISES), hosts an annual conference and educational programs, providing financial, academic and cultural support to American Indians and Alaska Natives from middle school through graduate school.

Besides professional groups, other networks are being created for people from underrepresented groups. The Midwest Consortium for Latino Research (MCLR) is a regional and multidisciplinary consortium to provide leadership for the advancement of Latino/a scholars in Midwestern institutions and research on Latino/as in the Midwest. MCLR has undertaken a variety of initiatives, including annual roundtables/conferences focusing on faculty development issues, assessment of academic environments through surveys, and creation of a Latino resource directory and database.

Other programs focus on professional socialization in academia. PROMISE, a partnership of Maryland's public research universities, focuses on issues associated with recruitment, retention, and professional development for graduate students transitioning into the professoriate. PROMISE, while focused on STEM disciplines, is open to graduate students from all fields. Their approaches include retreats, seminars, and conferences.

Professional socialization is an important component of the Minorities Striving and Pursuing Higher Degrees of Success (MS PHDS) program. Participation in conferences, field trips, mentoring relationships, the facilitation of networking opportunities, and active membership in an on-going community of educators involved in facilitating participation of minorities in Earth System sciences are key components of this program which is expected to directly and deeply impact the lives of over 100 minority Earth System Science undergraduates, graduate students, and recent graduates. These are complemented with financial support for education and related experiences (Pyrtle and Williamson, 2007). Although rigorous demonstrations of efficacy of these professional societies is challenging, mainly due to the absence of comparison groups and selection bias, qualitative data strongly supports the efficacy of this approach.

Programs Involving Mentors

Formal mentoring programs are most common at the college and graduate school level, reflecting the belief that mentoring is a component of professional development. Mentoring can also be effective for junior faculty from underrepresented groups (Girves, Zepeda, & Gwathmey, 2005). It is an element of numerous successful programs and is often considered to be a critical component. In a survey of 9,000 doctoral candidates, Nettles and Millett (2006) identified mentors – that is, faculty members who are a source or advice about academic issues as well as a source of support and encouragement – as being associated with rate of scholarly publishing, degree completion, and time to degree. Interestingly, having a mentor was independent of race.

In conducting mentoring programs, consideration should be made as to who will be the most appropriate mentor. The LSAMP program evaluation (Sharp et al., 2000) reported peer mentoring was a major and important component of their bridging programs during the first two years of college. Faculty mentors were harder to relate to and not used to help address personal problems; peer mentors were seen as being friendlier and more supportive.

As with many of these programs, mentoring programs use multiple strategies to increase the proportion of people from underrepresented groups in STEM. Mentors often provide professional socialization and career awareness to people from underrepresented groups. As will be evident below, mentors can help provide students with access to information they may not obtain elsewhere. In that mentoring programs are trying to provide students with additional supports they might not receive or information to which they might not have access, these programs may be considered leveling the playing field. Below we describe several mentoring programs.

The Significant Opportunities in Atmospheric Research and Science (SOARS) program has involved 85 undergraduates from underrepresented groups since its inception in 1996. None have left college without earning a STEM degree. Their program places a strong emphasis on mentoring. At the beginning of this summer program, students are provided with a science research and a scientific writing and communication mentor. New students are also provided with a community mentor (knowledgeable about the local area) and a peer mentor. As previously noted, the success of a program like SOARS cannot be attributed to a single factor. SOARS provides support for up to 4 years (and for graduate school); an extended learning community; and encouragement to work outside of one's comfort zone (Windham, Stevermer, & Anthes, 2004). Nonetheless, the quantity and diversity of SOAR's mentoring is a distinctive feature of the program.

The Summer Research Opportunities Program (SROP) is a program designed to engage underrepresented minority students in research experiences with faculty mentors. The program intends to socialize students into a discipline while promoting the creation of a community of scholars. The program consists of one-on-one research internships with faculty mentors, weekly campus-based educational enrichment activities, and a summer research conference with the goal of preparing and encouraging the pursuit of graduate study and academic careers. Compared to the general student population, the retention, graduation, and post-baccalaureate enrollment rates of SROP students are considerably higher (Girves, Zepeda, & Gwathmey, 2005). Approximately

74 percent of the SROP alumni enrolled in graduate and professional schools and about 58 percent of them have completed advanced degrees (Foertsch, Alexander, & Penberthy , 1997).

In 2004, BEST labeled the Compact for Faculty Diversity (Compact) and the Preparing Future Faculty (PFF) programs as exemplary for building the faculty of the future. The Compact is a partnership of regional, federal and foundation programs that focus on education and faculty diversity with the goal of increasing the number of people from underrepresented groups earning doctoral degrees and becoming college and university faculty. The Compact provides financial and academic support, mentoring, and professional development to doctoral students from underrepresented groups who aspire to careers in the professoriate. It also sponsors the Institute on Teaching and Mentoring that brings together graduate students, postdoctoral fellows, and faculty mentors from colleges and universities throughout the nation to discuss strategies for success in graduate school and preparation for academic careers.

The PFF Program is a national initiative to develop new models of doctoral preparation for a faculty career by including preparation for teaching, academic citizenship, and research. PFF programs expose students to the full scope of faculty roles and responsibilities (i.e., teaching, research, and service) while emphasizing how the expectations for these often differ in different campus settings and provide access to multiple mentors and reflective feedback. Often the students work with an assigned mentor at another institution.

Programs that Address Academic Isolation

Hagedorn et al. (2007) feels that a critical mass of people with a shared social identity is crucial for having students believe they belong in their academic setting. Almost by definition, MSIs will eliminate a sense of social isolation – at least for the predominant minority group(s) on campus. At other institutions of higher education, there are programs which seek to create a cohort of students entering the program/university at the same time creating a critical mass. Several of these programs also recognize that more than a critical mass is needed and provide additional supports to students, such as academic and professional socialization. Creating a critical mass may be seen as "leveling" the playing field by removing the barriers of social isolation.

The absence of academic isolation for African Americans at HBCUs almost certainly has contributed to their success in producing earth science graduates. Jackson State University's meteorology program has been in existence for over 30 years. About one-quarter of the undergraduate atmospheric science B.S. degrees earned by African Americans were awarded by this program. The Howard University Program in Atmospheric Sciences (HUPAS) is the first and only program offering graduate degrees in atmospheric science at an HBCU. In 2006, there were 23 graduate students from underrepresented groups enrolled in this program (Misra, Carruthers, & Jenkins, 2006). If one-third earned a graduate degree in 2006, the proportion of students from underrepresented groups earning graduate degrees in the geosciences would be increased by one percent.

At MSIs, academic program development approaches have been adopted in the aquatic sciences to enable students to become aware of these disciplines in environments in which students from underrepresented groups are not underrepresented. Marine science degree programs have been established in at least 7 MSIs (Hampton University, Savannah State University, the University of Puerto Rico, Jackson State University, University of Maryland – Eastern Shore, Fort Valley State University, and the University of the District of Columbia). NOAA, through its Educational Partnership Program, established five Cooperative Science Centers (CSC) at MSIs. Hundreds of students have received undergraduate and graduate degrees through these CSCs. The CSCs are undergoing formal evaluations of their education, scientific, and administrative components. It is anticipated that these evaluations will demonstrate the positive impacts of their various approaches.

To directly deal with the issue of social isolation, ocean scientists at Hampton University, Old Dominion University, and Virginia Institute of Marine Sciences (VIMS), with the support of NSF, formed the Hall-Bonner Program (Cuker, 2005). This program provides full support for graduate students to attend one of the three participating universities. The Hall-Bonner scholars meet regularly, interacting on both a formal and informal basis, and serve as a peer-support group.

Combining efforts across institutions was also used by the Alliances for Graduate Education in the Professoriate Program (AGEP). AGEP combined two NSF Minority Graduate Education (MGE) projects at the University of North Carolina at Chapel Hill and the joint North Carolina State University (NCSU)/North Carolina Agricultural and Technical State University project and created NC OPT-ED. The subsequent substantial increases in the numbers of STEM graduate students and STEM earned doctorates at these schools is a likely concomitant of the strategies employed at these MSIs. These strategies include a yearly, all-day event joining students from all collaborating institutions, consisting of workshops, student presentations, and a keynote address targeted to the unique needs of students from underrepresented groups. Additional meetings are held three times a year to provide opportunities for graduate students from underrepresented groups from across the Alliance to come together for informal conversations (e.g., discussion groups, networking, programmatic activities, and socialization).

While MSIs may have a built-in critical mass, some programs at Predominantly White Institutions (PWIs) attempt to create a critical mass of students to reduce academic isolation. The Meyerhoff Program at the University of Maryland, Baltimore County (UMBC) has been very successful in supporting African Americans in their pursuit of STEM degrees. In comparison with students who were invited to participate but chose to attend school elsewhere, program graduates were twice as likely to earn science or engineering B.S. degrees and more than five times as likely to enroll in graduate studies (Maton, Hrabowski, & Schmit, 2000; Maton & Hrabowski, 2004). This program was specifically designed to deal with academic and social integration, along with the provision of motivation and support, knowledge and skills, and monitoring and advising (Woolston, Hrabowski, & Maton, 1997). Specific strategies employed for these purposes include financial support, freshmen orientation programs, recruiting active science researchers to work with the students, involving students in research as early as possible, and selective recruitment of high-achieving minority students with STEM interests (Summers and Hrabowski, 2006). All of these approaches may be labeled as leveling the playing field approaches. The group activities, team building events, and team travel undoubtedly ameliorate issues of isolation and contribute to the program's overall success rate.

At Oregon State University, a PWI, the Native Americans in Marine Science (NAMS) program, has produced a 95 percent retention and graduation rate for 155 student from underrepresented groups. Over half of these students subsequently enrolled in graduate degree programs (Oregon State University, 2009). This program has evolved into Native Americans in Science, Engineering and Natural Resources (NASENR) and now provides paid internship opportunities for Native American and Alaskan Native undergraduate students, to deal with issues of isolation and poor academic preparation (leveling the gap approaches) as well as increase their awareness of opportunities in the ocean sciences (an attraction to a specific discipline approach).

Programs that Incorporate Field Trips

The prevalence and importance of field trips in geoscience education distinguishes the geosciences from other STEM fields. Geoscience research field trips often involve camping and overnight stays. These trips promote socialization, providing students an opportunity to bond with other geoscience majors as well as with faculty. They also provide students with geosciences research experiences. Positive field trip experiences are factors associated with recruitment and retention that appear to be geoscience-specific. For example, one critical incident respondent spoke about field trip activities that introduced him to different aspects of the geosciences and also made the material more relevant (Levine et al., 2007).

Field trips are a very common approach for programs trying to increase diversity in the geosciences. In 2005-2006, there were 50 projects that received funding from NSF's Opportunities for Enhancing Diversity in the Geosciences (OEDG) programs. Well over half (58 percent) of them used field trips as one of their strategies for promoting diversity. It is noteworthy that many of these field trips and outdoor experiences are provided to younger children. CAMP SEA Lab's program for elementary school children resulted in knowledge gains and attitude changes consonant with retention in a geoscience career pipeline (Crane, 2007). In addition to visits to national parks and outdoor experiences, the informal education experiences provided by museums and planetarium have undoubtedly had profound impacts on many.

Programs that Provide Geoscience Research Experiences

Cole and Barber (2003) suggest that early mentoring and research experiences are critical activities in attracting high-achieving undergraduates from underrepresented groups into academia. The opportunities to get involved with "real" research provide students with opportunities to learn what specific science disciplines and what research "really" are. When such experiences are provided in a supportive and encouraging environment (which is often a new and different environment for the student) there can be profound impacts on the student. Several such programs have been very successful in attracting students to the geosciences. These programs are typically for college students, based on the belief that a core set of skills and knowledge are required to enable students to benefit from such experiences.

The Minorities in Marine Science Undergraduate Program's (MIMSUP) goal of providing each student with the experience of conducting an individual, supervised research project, analogous to a beginning graduate student's experience is believed to be a key component of their success (Bingham et al., 2003). For many students, in-depth exposure to a specific discipline (and to the people working in the discipline) will help attract them to this discipline. Of the 103 MIMSUP participants between 1991 and 2003, 100 have either completed or are currently enrolled in an undergraduate program. Of the 78 graduates, 51 have earned graduate degrees or enrolled in graduate programs.

Savannah State University's Research Experience for Undergraduate (REU) program provides these experiences to early undergraduates, prior to their choice of majors. It tries to bridge academics and research by providing four weeks of lectures, labs, and field trips as preparation for five weeks of formal research projects at Harbor Branch Oceanographic Institution, helping to attract them to the discipline. In conjunction with an internship program with the Skidaway Institute of Oceanography, nearly two-thirds of Savannah State University's marine science B.S. graduates participate in intensive research experiences (Gilligan, 2001; Gilligan et al., 2007), providing them with knowledge and experience that levels gaps as well as promoting retention in the marine sciences.

Programs that provide employment opportunities

Programs that result in near-certain employment opportunities at reasonable salaries will attract many students to a specific career. When these programs are offered at minority serving institutions, they will promote diversity in the field. Such programs are targeted to college and graduate students. For example, NOAA and Jackson State University offer an intensive program to train students for positions in fish population dynamics/stock assessment, a field anticipating substantial labor shortages. This program, involving both summer course work and a 4 – 8 week internship provides a vehicle for doing more than leveling the play field. It attracts and prepares students from underrepresented groups for professional careers in oceanic sciences. After the program, students reported they were more likely to consider fish stock assessment/ population dynamics as a career[7] (Chigbu and Fogarty, 2007).

Another program, at California State University – Dominguez Hills, prepares students with hands-on experience in a specific field which can lead directly to employment opportunities: Tracking MTBE contamination of ground water. MTBE is a gasoline additive that was used until it was declared a significant risk to the environment and a threat to ground water and drinking water in 1999. Students are made aware of the employment opportunities provided by this training. Two-thirds of the students in this program reported that obtaining a job was an important or very important reason for taking this class (McNulty, 2007).

The Southern Regional Education Board's (SREB) Doctoral Scholars was established in 1993 to address the national shortage of faculty from underrepresented groups at institutions of higher learning. SREB states share resources, work to expand their minority applicant pool, support qualified candidates with financial assistance, and assist graduates and higher education institutions in identifying employment opportunities. This program provides financial resources, professional development, mentoring, and networking to Ph.D. students and it is the lead host of the largest annual gathering of minority doctoral students and faculty mentors in the US, the Compact for Faculty Diversity Institute on Teaching and Mentoring. The program has helped more than 400 Ph.D. graduates earn their degrees and currently assists more than 300 Ph.D.

[7] Only 15 of 40 participating students responded to this post-participation survey, limiting generalizability.

students. The program has a retention/graduation rate of nearly 90 percent and more than 70 percent of its graduates have begun academic careers in higher education.

Many of OEDG's programs provide information about career opportunities in the geosciences (rather than direct employment opportunities). Such strategies can be very useful for both attracting students to the field and retaining them in geosciences majors. However, firm evidence of the efficacy of this approach is challenging to demonstrate. That is, while several OEDG programs were able to demonstrate they successfully changed students' beliefs about geosciences salaries (through increases in agreement with the statement that "Geoscientists are well-paid"), changes in this belief did not translate into changes in intention of pursuing a geosciences career. This is not surprising, given the huge number of factors that contribute to career choice. Nonetheless, there appears to be little downside associated with the presentation of positive information about geosciences careers.

Programs that are culturally relevant

Programs that are culturally relevant are targeted to students with specific, common cultural backgrounds. Yup'ik Mathematics (discussed previously) and the Algebra Project are examples of programs that attempt to level the playing field for K-12 students through culturally relevant instruction. The Algebra Project is based on the belief that the conceptual shift from arithmetic to algebra is a major block to studying higher mathematics. By focusing on the everyday experiences of urban, African American youth, problems relating to travel on urban transit systems were used as teaching tools. Similarly, ratio and proportion educational units used African drumming traditions for instructional purposes. Such approaches allow students to become “competent members of both their home communities and the academic community” (Nasir, Roseberry, Warren, & Lee, 2005). These practices, often called culturally relevant teaching, are important strategies to use in teaching minority students. Culturally relevant teaching is seen as a way to incorporate students’ knowledge and ways of learning in the classroom to achieve greater academic success (Gay, 2000).

Culturally relevant courses can also help attract students to specific disciplines as well as level the playing field. A course in the Geology of Africa increased the number of African Americans taking geology at Hamilton College from 3 (5 percent) to 11 (17 percent) (Tewksbury, 1995). A course on the Nile River was reported to increase the number of African Americans taking geosciences courses at Pennsylvania State University (Zappe, 2007).

Cultural beliefs are sometimes at odds with science and misconceptions emerge because the students’ worldview is in conflict with a scientific worldview. Social, epistemological, and religious beliefs influence views about the origins of human life, creating a predicament when people cannot accommodate the concepts of the theory of evolution within their “cognitive culture” (Hokayem & BouJaoude, 2008). Debates regarding how to handle this issue within the educational system are still unresolved. Some suggest teaching alternatives of the theory in order to give students a thorough appreciation of the variety of views on the subject and to allow them to critically evaluate their own views (Campbell & Meyer, 2005; Rankey, 2003). However, others argue against introducing this type of controversy into the classroom (Pennock, 2002). As noted by Dutch (2002), “When scientists deal with issues like creationism, the widespread failure to understand how religions regard their doctrines frequently results in miscommunication and ineffective, even counter-productive, strategies. The unspoken assumptions made by scientists and dogmatic religious believers are so different that in extreme cases meaningful communication may be impossible." Therefore, it is important to address cultural beliefs in order to establish communication channels that will help to integrate the students and scientific worldviews in a positive way.

The conflict between traditional, Native American knowledge and traditional western science has been a barrier to effective geoscience instruction. Place-based teaching, in conjunction with efforts to present material in ways that are consistent with traditional beliefs, has lead to more culturally related pedagogy (Semken, 2001; Baker, 2000). Culturally sensitive programs have had positive impacts on Native American high school students, enhancing their awareness of geosciences careers and their interest in taking related courses in college (Riggs, Robbins, & Darner, 2007).

Programs that provide accommodations for people with disabilities

Disabilities, Opportunities, Internetworking and Technology (Do-It) is a program that assisted high school students with disabilities through the provision of computer hardware and software, in efforts to level the playing field. They also provided *training in self-advocacy*, along with work experiences and a 2-week summer study/bridging program at a university. Although labeled (by BEST) as an intervention that would "Benefit from Further Research," we were impressed that 90 percent of the program graduates enrolled in college and 26 percent had already graduated from college.

A study of 286 STEM professionals with disabilities about behaviors that either facilitated or hindered their entry into and advancement within STEM professions produced a taxonomy that enabled identification of very specific barriers and facilitators. “Addressing Barriers” emerged as a major domain of behaviors. This domain included obtaining accommodation in school and work settings; developing creative solutions to address barriers; gaining physical access; acquiring access to and using technology, seeking legal recourse, and obtaining financial aid (Weisgerber, Levine, DuBois, & Stern, 1990). NSF’s Program for Persons with Disabilities in STEM Education (PPD) was positively evaluated by a Committee of Visitors. They found the program succeeded in developing new knowledge and techniques to assist students with disabilities in science and engineering courses (NSF, 2000; 2003).

Programs that facilitate transitions between schools

Bridging programs are designed to facilitate the transition between schools (with a particular emphasis on the transition from high school). Bridging programs employ a range of strategies and often address academic preparation, social isolation. They may also include financial support. The bridging programs that we reviewed predominantly employed “leveling the playing field strategies.” However, at the high school to college transition levels, the use of strategies to attract students to specific disciplines was not uncommon.

Bridging programs were deemed to be the most successful feature of Louis Stokes Alliances for Minority Participation (LSAMP) Programs (Sharp, Kleiner, & Frechtling, 2000). LSAMP programs employ a variety of different strategies, are often targeted to specific underrepresented groups, and are targeted at different transition points. Most are intended to facilitate the transition to college. LSAMP programs typically pay students to attend a 3- to 6-week session prior to enrolling in college. The students enroll in gatekeeper courses (such as math and science) to help ameliorate any deficiencies in their prior education. Many of these programs also teach time management, study skills, and other skills that are intended to facilitate the transition to college. These approaches attempt to level the playing field (with respect to academics, social and study skills, and fiscal support) – and occasionally go beyond. The provision of research experiences, which is common among LSAMP programs, was felt by LSAMP staff and students who survived freshman year, to be the most important program feature.

Hanks et al. (2007; 2007a) incorporated a four-credit, college-level, field-intensive introductory geoscience course in a bridging program for rural Alaska high school students. Students enrolled in the bridging program were significantly more likely to complete a bachelor's degree program at the University of Alaska than rural Alaska natives who did not participate in the program. The addition of a component intended to attract students to a specific discipline appeared to be quite effective. Students participating in the program's geoscience course (compared to students enrolled in other courses) showed significant gains in their knowledge of geosciences careers, their attitudes about the geosciences, and an increased likelihood of choosing a geosciences major.

A pre-engineering program at the University of Akron, part of Upward Bound, also found success through its bridging program (Lam et al., 2005). The program, targeted to low-income African American high school students, included a six-week summer residential program, with an integrated curriculum in mathematics, science, language arts, technical writing, and computer science. The summer component had numerous transition activities, such as peer mentoring, study skills, and academic advising. This bridging program also included components during the academic year such as tutoring and academic workshops. Participation in the program resulted in increased grade point average and better attitude towards STEM (i.e., less anxiety toward math and sciences, increased self-efficacy in STEM). The college freshman summer bridge program has also had a positive impact on those students entering college. Ninety-four percent of participants entered college and 66 percent majored in STEM.

The Academic Investment in Math and Science (AIMS) Program of Bowling Green State University (BGSU) also is a bridging program that provides support for students prior to entering college, and continues to support them during college (Gilmer, 2007). This program has three major phases: 1) a five week Summer Bridge Program, 2) a freshman-sophomore phase where students enroll in courses as a cohort, and 3) participation in STARS (Students Teaching And Reaching Students), where participants study together as group, receive mentoring, participate in research, receive career development, amongst other supports. Students who participated in the program had average GPAs of 3.0, whereas a control group had an average GPA of 2.5. This program has also had a good retention rate, retaining 93 percent of the 2002-2004 cohorts after the first year, and 89 percent of the 2002 cohort after three and a half years. (The national retention level for students in STEM is 60-65 percent.)

Bridging programs at all transition points do not appear to be necessary. Since the loss of graduate students from underrepresented groups from the master's to Ph.D. levels is small, Huntoon and Lane (2007) believe that the geosciences are effective at retaining these students during the transition from master's to Ph.D. programs (or they may be very effective at recruiting Ph.D. students from other STEM fields).

Programs to Encourage Family Support

Parental influence on college major choice differs as a function of race/ethnicity. Among whites, both parents have a substantial influence. Among African-Americans, only the mother's influence has substantial impacts (Maple & Stage, 1991; Gruca, Ethington, & Pascarella, 1988, as cited in Huang, Taddese, & Walter, 2000). We did not find evidence of effective programs whose primary objective was the development of parental support for geosciences careers.

Nonetheless, many programs, particularly for K-12 students, incorporate activities at which parental involvement is encouraged. Several NSF grantees from the Opportunities for Enhancing Diversity in the Geosciences (OEDG) program, in recognition of parental barriers to recruiting participants for their program, would meet and discuss their programs with parents and family members, to obtain the necessary buy-in (Fuhrman, González, Levine, & Martínez-Sussmann, 2004).

Programs that provide financial support

Financial support is an "enabling" strategy that is incorporated into dozens of different programs intended to encourage the participation of people from underrepresented groups in the geosciences. This strategy recognizes that participation in any program represents an opportunity cost for the participant. Financial support is generally more important for undergraduate and graduate students and represents an attempt to level the playing field. Nonetheless, for high school students who work, participation in summer programs might be difficult if they do not receive financial compensation. Similarly, programs intended to provide professional development for K-12 teachers in the geosciences often provide stipends for teachers.

Financial support may come in the form of scholarships and fellowships or support for other scholarly endeavors such as money to attend a conference. Numerous programs mentioned, such as the University of New Orleans geoscience program for high school students, Minorities Striving and Pursuing Higher Degrees of Success (MS PHDS) program, Compact for Faculty Diversity, the Meyerhoff program, and the SREB Doctoral Scholars provide financial support to all participants.

The National Science Foundation (NSF) offers a number of fellowship and other support programs. NSF's Minority Graduate Fellowship program, in response to legal challenges, was incorporated in the Graduate Research Fellowship program. Support from this program helped improve the Ph.D. completion rate, but even among fellows, the completion rate was substantially lower for minorities (61 percent) than for non-minorities (74 percent) (WestEd, 2002). NSF's Minority Postdoctoral Research Fellowship was positively evaluated by former recipients. Eighty percent felt the program enabled professional development, enhanced research skills, and promoted focus of their research efforts to a degree that would not have been otherwise possible. Over half of the recipients applied for research grants; 81 percent of these had received funding (SRI International, 2004).

For both of these programs – as well as other NSF programs, such as the Integrative Graduate Education and Research Traineeship (IGERT) program, there is good evidence of the success of leveling the financial playing field. However, success for minorities supported by these programs lags success for majority group members (CEOSE, 2004). These programs have not been examined with respect to success rates for specific scientific disciplines, preventing assessment of their geosciences specific impact.

Similarly, the National Oceanic and Atmospheric Administration (NOAA) offers fellowship and other support programs. NOAA offers graduate training for students from underrepresented groups who seek employment with NOAA through its Graduate Sciences Program (GSP) and stipends plus paid summer research internships at NOAA facilities to students at MSIs through its Undergraduate Scholarship Program (USP). Between 2000 and 2007, 39 GSP graduates were hired by NOAA and 70 percent of the GSP completers have gone on to graduate school (NOAA Office of Education, 2008).

Financial support does not have to be provided directly by a program: provision of knowledge about sources of funding is another type of financial support. Several bridging programs, including the Pathways Program (at the University of Texas, El Paso) and the Rural Alaskan Honors Institute (RAHI) provide instruction about college scholarships, fellowships, loans, and other approaches to help finance higher education. Their participants typically report increases in their knowledge of financial support and the college application process after these programs (Hanks et al., 2007; Miller et al., 2007).

Activities that expose students to the culture of geosciences

Informal interactions and social activities in the geoscience department were geoscience-specific behaviors identified in the critical incidents as being responsible for attracting and retaining individuals in the geosciences (Levine et al., 2007). In contrast with the competitiveness characteristic of other STEM disciplines, many students see the geosciences as being more cooperative. The geosciences culture, characterized by positive, informal interactions with faculty and with other students, promotes attraction to the field and retention. Social gathering for geosciences majors provide opportunities for interactions with non-majors. One critical incident respondent reported that this was the source of her initial exposure to, and interest in the geosciences. Such exposure is an implicit component of nearly all programs. We mention it to make salient its potential impacts.

NOAA's CSCs have resulted in the creation of oceanic/atmospheric degree programs at the undergraduate level at North Carolina A&T State University and California State University, Fresno and at the doctoral level at Howard University. Florida A&M added an environmental science course for non-majors; the City College of CUNY established a new multidisciplinary Engineering and Science curriculum focusing on remote sensing. Creating such programs and offering them at MSIs can only increase the number of students exposed to the culture of geosciences and atmospheric and ocean sciences. As previously noted, there is an on-going evaluation of NOAA's CSCs, which should inform about the effectiveness of this approach.

Strategies Summary

Given the numerous hurdles that students from underrepresented groups face, universities, K-12 school systems, non-profits, and other organizations have developed a wide variety of strategies to increase the recruitment and retention of such groups in STEM fields and in the geosciences. In this section we described thirteen strategies that are major components of different programs to ameliorate this underrepresentation. Many programs utilize more than one strategy and these strategies target different populations, with varying foci, and approaches.

A strategy may be operationalized in different ways to address hurdles confronted by persons of underrepresented groups. Strategies might focus on affecting structures (e.g., at the university level) or individuals. Strategies may vary to meet the needs of participants of different ages, thus the target group and the approach differs. To address career awareness and professional socialization, programs aimed at high school students might provide information on geoscience careers, programs aimed at undergraduate and graduate students might provide opportunities to present at a conference, and programs aimed at Latino faculty might provide a forum to discuss career development. In addition, some strategies address multiple hurdles. Conferences from societies targeted at minority students may provide professional socialization and reduce academic isolation. In the next section, we attempt to link specific strategies to the specific barriers and hurdles that we feel they were developed to address.

SUMMARY/CONCLUSIONS

Table 1 summarizes the different barriers that have been discussed and the different strategies that have been developed and implemented to deal with these barriers. Strategies are also categorized with respect to whether their underlying goals are to level the playing field or to attract students to a specific discipline. Nine of the 16 strategies listed in the table are exclusively focused on leveling the playing field. Only two strategies (those that address cultural relevancy and those that expose students to the culture of the geosciences) are exclusively intended to attract students to a specific discipline. Although determinations about which specific strategies will be most effective for overcoming specific barriers cannot be made a priori, we hope this table will be beneficial for those planning and implementing programs.

INSERT TABLE 1 ABOUT HERE

In 2001, the American Association for the Advancement of Science produced *In Pursuit of a Diverse Science, Technology, Engineering, and Mathematics Workforce: Recommended Research Priorities to Enhance Participation by Underrepresented Minorities* (George et al., 2001). A study group of 70 STEM educators and researchers met in September 2000; 150 research studies were reviewed. They noted, “The current research base provides limited potential for thorough analysis for several reasons” (p. 12). These included a lack of established guidelines for researchers, resulting in studies that are not directly comparable because of definitional and methodological issues; a lack of disaggregated information … and studies that are only conducted at one university (or one type of university, hindering generalizability).

In 2004, CEOSE noted, “Key programs and projects at NSF and grantee institutions need systematic formative and summative evaluation with respect to their impact on broadening participation, to understand what works, what does not work, and why.” (CEOSE, 2004, p. xv). This sentiment was echoed by the Second Geoscience Education Working Group: “There needs to be a standard approach to data collection that can be use by all PIs and NSF Program Officers to critically evaluate projects… Evaluation data are necessary for identification of best practices and for determination of the collective impact of GEO education programs. PIs may need assistance to effectively incorporate evaluation into their projects. NSF should provide this assistance.” (Huntoon et al., 2005, p.16). These same concerns are salient today.

Nonetheless, our understanding of what appears to be working, for whom, and why it appears to be working has been enhanced by continuing research efforts. We can identify specific interventions that are effective in leveling the playing field for students from underrepresented groups, particularly with respect to the acquisition of math and science knowledge and skills at the K-12 level. We can draw inferences about the characteristics of interventions that will reduce the knowledge gaps in other academic areas and reduce the gaps in skills, abilities, attitudes, and beliefs that hinder people from underrepresented groups in their pursuit of STEM careers. We can draw inferences about the characteristics of programs that level the playing field for students from underrepresented groups majoring in STEM at the post-secondary level and the factors that will facilitate their retention in a STEM career pipeline. We can identify different factors and different types of interventions that appear to be successful in attracting students to specific disciplines.

Much remains to be learned. We can continue to learn what is working and why if we are willing to continue to invest in these efforts. Support of standard approaches and model driven evaluations should be encouraged. A deeper understanding is possible through mixed methods research methods, employing both qualitative and quantitative research methodologies.

Embedding research design into interventions should also be encouraged. The possibility of designing and implementing programs in which key components are manipulated (such as having half of the participants receive peer mentoring and the other half receive study skills training) and their impacts evaluated through the use of standard, model-based metrics, can increase our knowledge of what works and why it works in a relatively cost-effective fashion.

Table 1. Barriers to Earth, Ocean, and Atmospheric Science Career Choice and Development for People from Underrepresented Groups and Types of Strategies for Overcoming these Barriers

	Barriers and Hurdles											
Strategies: Programs that address...	Small size	Awareness of geoscience	Outdoor education/ experiences	Cultural barriers	Racism & negative stereotypes	Financial stress	Academic isolation	Lack of social support from peers & family	General academic preparedness	Lack of familiarity with STEM careers	Lack of familiarity with higher education	Perceptions of ability & self-efficacy
Academic Preparation									L			
Career Awareness	L	A								L		
Professional Socialization							L				L	
Peer Mentoring							L	L			L	
Faculty Mentoring										L	L	
Academic Isolation: MSIs					L		L					
Academic Isolation: PWIs		A			L		L					L
Field Trips		A	A, L							L		
Research experience		L	L			L			L	L		L
Employment Opportunities		A				L				A		L
Cultural Relevancy				A	A							
Accommodations with people with disabilities					L							L
Transitions between Schools		A				L	L		L		L	L
Encourage Family Support	L							A		A, L		
Financial Support						L					L	
Culture of Geosciences	A	A										

NOTE: A = Strategy is intended to attract student to a specific discipline; L = Strategy is intended to level the playing field

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