

Improving Underrepresented Minority Student Persistence in STEM

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ABSTRACT

Members of the Joint Working Group on Improving Underrepresented Minorities (URMs) Persistence in Science, Technology, Engineering, and Mathematics (STEM)—convened by the National Institute of General Medical Sciences and the Howard Hughes Medical Institute—review current data and propose deliberation about why the academic “pathways” leak more for URM than white or Asian STEM students. They suggest expanding to include a stronger focus on the institutional barriers that need to be removed and the types of interventions that “lift” students’ interests, commitment, and ability to persist in STEM fields. Using Kurt Lewin’s planned approach to change, the committee describes five recommendations to increase URM persistence in STEM at the undergraduate level. These recommendations capitalize on known successes, recognize the need for accountability, and are framed to facilitate greater progress in the future. The impact of these recommendations rests upon enacting the first recommendation: to track successes and failures at the institutional level and collect data that help explain the existing trends.

INTRODUCTION

The United States’ inability to achieve science, technology, engineering, and mathematics (STEM) workforce diversity goals has long been attributed to the failure of the academic “pipeline” to maintain a steady flow of underrepresented minority (URM) students. While there have been some gains, national data continue to show that the disparity in STEM degree attainment for URM students (i.e., African American, Hispanic or Latino/Latina, American Indian, and Alaska Natives) increases at each degree level, compared with white and Asian students (see Figure 1). We propose that deliberation about why the “pipeline” leaks more for URM than white or Asian students should be expanded to include a stronger focus on the institutional barriers that need to be removed and the types of interventions that “lift” students’ interests, commitment, and ability to persist in STEM fields.

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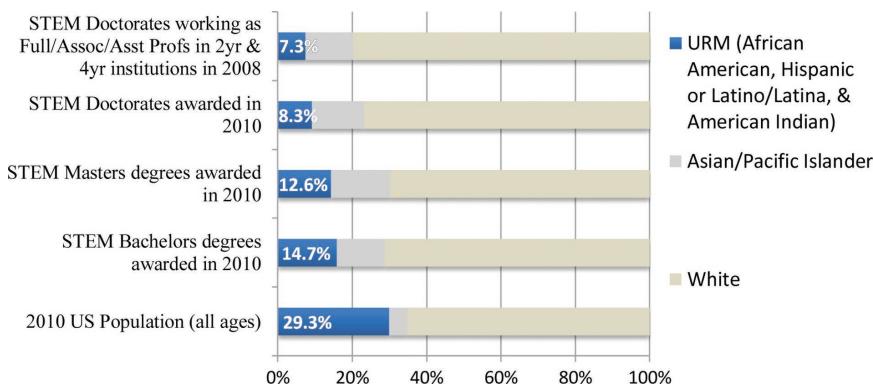


FIGURE 1. Current percentages of underrepresented minority, white and Asian/Pacific Islander populations with STEM degrees. URM includes African American, Hispanic or Latino/Latina, American Indian, and Alaskan Native. In this analysis, “STEM degrees” includes degrees categorized by the NSF as “Science & Engineering” (but excludes degrees in psychology and social sciences) in data tables prepared by the National Center for Science and Engineering Statistics based on data from the U.S. Department of Education’s IPEDS 2010 Completions Survey. Sources: population: U.S. Census Bureau, 2010 Census Summary File 1, tables PCT12H, PCT12I, PCT12J, PCT12K, PCT12L, PCT12M, PCT12N, and PCT12O; degrees: NSF, National Center for Science and Engineering Statistics, special tabulations of U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey, 2001–10; and faculty: National Science Foundation statistics.

As members of the Joint Working Group on Improving URM Persistence in STEM—convened by the National Institute of General Medical Sciences (NIGMS) and the Howard Hughes Medical Institute (HHMI)—our charge was to review current literature and explore barriers to undergraduate URM STEM persistence from a fresh perspective and enable constructive, innovative thinking regarding solutions. The committee was composed of educators with deep experience in addressing URM persistence in STEM, who convened for several multiday formal meetings and sustained ongoing conversations over the course of the past 3 years. Despite committee members’ diversity in culture, training, and professional experiences, we strongly converged around the belief that 40 years of intervention experience supported by NIGMS, HHMI, National Science Foundation (NSF), and other funders, coupled with more recent experimental research, has given us sufficient knowledge to address the disparity in STEM fields much more effectively. As a starting point, we address the pervasive pattern wherein URM students plan to undertake STEM majors in college at the same rate as do white students but do not graduate with STEM degrees at that same rate (Hurtado *et al.*, 2009; Presidential Council of Advisors on Science and Technology [PCAST], 2012). The main problem now appears to be that there has not been a national commitment to enact and sustain the institutional initiatives necessary to capitalize on what we know and systematically track successes and failures as we move forward.

Planned Approach to Change

In the 1940s, Kurt Lewin proposed a now classic planned approach to change involving the concepts of field theory, action research, and a three-step model (Lewin, 1946, 1947). His theory (and method) for change provides a context in which

to place the proposed recommendations of the working group. According to field theory, a variety of forces maintain the status quo through contextual and individual inputs such as culture, values, norms, and roles. Change begins by recognizing the fields of influence in a situation and identifying the points at which there are “gatekeepers” that impede the flow of change in a system.

According to Lewin, group, organization, or social system change does not occur by simply shifting individual behavior but requires the larger system to shift as well. Lewin’s three-step model, which dominated the field of change management for nearly 40 years and continues to be discussed as relevant (see Burnes, 2004), provides an approach for creating system change. Lewin’s model describes the backbone to many change theories (Sarayreh *et al.*, 2013) and shares elements with Elrod and Kezars’ (2015) newer, more detailed Keck/PKAL model for institutional change or Austin’s (2011) description of how to promote evidence-based change. First, as Lewin

describes it, a system or organization must become *unfrozen*, which can occur from destabilization or from creating awareness that the status quo no longer is functional to achieve the aims of the group, institution, or larger social system (Lewin, 1947). Second, the system experiences *moving*, which for Lewin involved an iterative process of engaging *action research* (see Figure 2). Action research classically is a spiral process that operates similarly to how a physician repairs a broken bone and includes the following steps: a) *evaluate*: collect information about the state of the situation; b) *diagnose*: use knowledge attained regarding the state of the situation and knowledge of what has worked in the past to identify the gatekeepers (aka barriers) and opportunities to improve the system; c) *plan*: create a plan of action; and then d) *take action*. After action is taken, return to “a” and reassess the situation—are things better or getting worse? Then one continues through the iterative process of adjusting the plan and implementations until the data show improvement. Importantly, this theory of change cannot occur without good data to inform the progress of change. Finally, when the system is in a new, functional, and perhaps thriving state, step 3, *refreezing*, occurs, which includes adopting the systems’ newer culture, policies, and practices (Cummings and Huse, 1989) and new norms and roles. The classical approach to action research recognizes the expertise of all persons involved in the system and encourages their active contribution to the change process.

With regard to addressing the issue of broadening participation, there was wide agreement that unfreezing (step 1) is occurring because the status quo is clearly not resulting in equity and broadening of the workforce (National Academy of Sciences, National Academy of Engineering, Institute of Medicine, 2007, 2010, 2011; PCAST, 2012; Carnevale and Strohl, 2013; Witham *et al.*, 2015). What follows are recommendations for

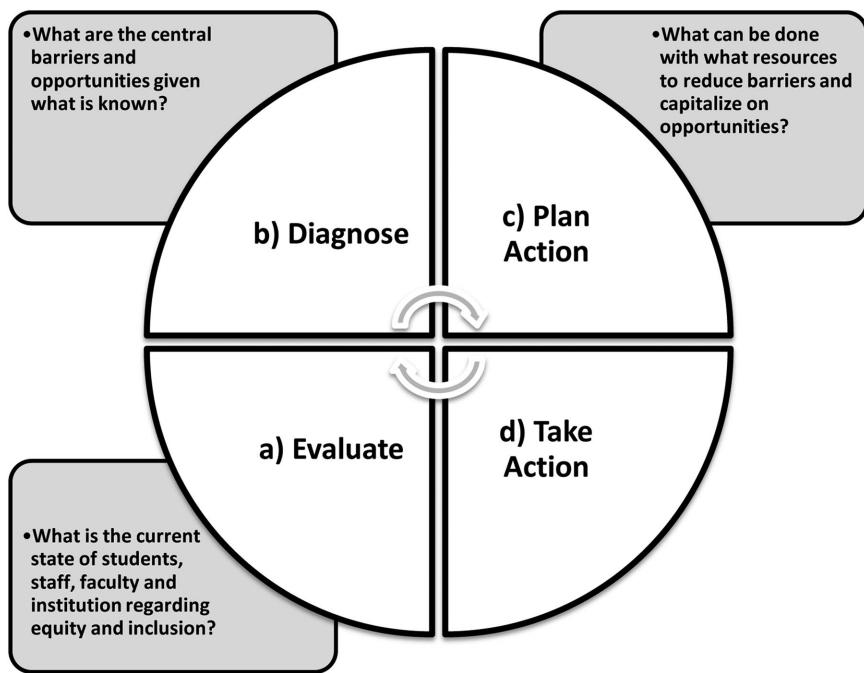


FIGURE 2. Action research model.

how to move the system by using an action research methodology, and as Lewin suggests, a key component to this is having data to inform us about the current state of the situation and provide evidence of change (or nonchange) as we move forward. Thus, the first recommendation is focused on acquiring quality information to create accountability. The latter four recommendations describe how to move the system by establishing new practices that shift the culture of science education. The goal is then to refreeze and gain the results that so eloquently describes: “To be stable … change must, in short, be a change in the ‘cultural atmosphere,’ not merely a change of a single item” (Lewin, 1943, p. 46).

ESSENTIAL FIRST RECOMMENDATION FOR PROMOTING CHANGE: TRACK AND INCREASE AWARENESS OF INSTITUTIONAL PROGRESS TOWARD DIVERSIFYING STEM

According to Lewin’s theory of change, iterative improvements of a group, system, or institution are greatly facilitated by clearly evaluating the state of the system to assess when change occurs (or not) and inform the diagnosis. Within the field of applied psychology, there is strong evidence that feedback promotes changes in behavior and can increase motivation for attainment of goals, because it creates accountability (Kluger and DeNisi, 1996). Consistent with this orientation, the Joint Working Group strongly recommends that decreasing URM and gender disparity begins with institutional accountability. Currently, there is no requirement for higher education institutions at the undergraduate level to know the ethnic identities of the students who enter, drop, or complete their degree programs. Because of this, such institutions that are successfully narrowing the STEM gap are not always identifiable; nor are institutions that are failing diverse students, perhaps miserably, held

accountable. To establish institutional benchmarks and encourage greater progress, institutional-level tracking by program of student ethnicity and performance outcomes must begin to occur in a uniform manner, such that comparisons can be made across time, departments, and institutions. What is now opaque can be made visible by systematically tracking the number of degree candidates and earners in STEM disciplines across demographic categories *and making those numbers publicly available* on institutional websites. In so doing, we 1) enable researchers and practitioners to identify institutions that are making progress (or not) and 2) allow for more careful data-driven analysis of what constitutes effective practices that can be adapted. *Federal and private funding agencies should require this information from institutions that receive support* in a standardized format that identifies disparity and equity. In addition, annual reports of institutional STEM data could be included in accreditation reviews. Most importantly, colleges and universities themselves stand to benefit from better institutional data on student performance and retention (Burnett, 2006; Hurtado *et al.*, 2009).

In addition to tracking student performance in STEM, institutional data should include time to degree, existing funded and unfunded URM intervention programs at the institution, and participation in research training experiences for URM and non-URM students. These data would considerably enhance educators’ and researchers’ ability to identify the characteristics of institutions with programs successful at recruiting and retaining URMs. Institutional data would complement current social science findings that show how empowering URMs with the skills, scientific identity, and values of scientists results in students experiencing greater integration into the scientific community and increases the likelihood of their persistence (Hurtado, 2010; Estrada *et al.*, 2011).

Some efforts have begun but are not comprehensive. For example, the National Center for Education Statistics conducts aggregate tracking of persistence in STEM across all colleges and universities in the United States. Their report on undergraduate attrition finds that 48% of the students who enter college with STEM majors leave those majors before graduation (Chen and Soldier, 2013). According to NCES, African-American students are the most likely ethnic group to leave STEM majors by dropping out of college (29%) or switching to a non-STEM degree (36%). There are relatively few reports of institutional-level tracking of STEM performance and persistence and fewer that provide analysis by ethnicity, although the NIH-funded Diversity Program Consortium seeks to track institutional data from multiple institutions from across the United States. Additionally, some institutions have begun internal tracking to understand their programs in relation to persistence and completion in STEM (Mercia 2010; Rask, 2010; Hill *et al.*, 2014), sometimes

TABLE 1. Summary of recommendations to increase the diversity of undergraduate STEM disciplines

Recommendations	Possible actions
1 Increase institutional accountability	Establish information systems across institutions that document 1) incoming student interest, 2) declared major, and 3) department/school/program graduation rates all (1–3) by student ethnicity, gender, socioeconomic status, and first-generation status. Make this information publicly available and reported to funding institutions.
2 Create strategic partnerships with programs that create lift	Program directors can begin by identifying the type of program one directs or wishes to direct. Possible variables to consider: 1) duration of the program, 2) context (i.e., type of university), 3) student type (e.g., low-, medium-, or high-risk/achievement/potential; culture; socioeconomic status; first-generation status; motivation), and 4) purpose/goals of the program (short, medium, and long term). Search literature for publications regarding programs like the one you want to direct. Communicate with funders about their knowledge of successful programs. Funders can facilitate greatly by supporting collaborations between successful and new programs.
3 Unleash the power of the curriculum	The learning sciences provide many publications that articulate curriculum best practices. Educators can expand their knowledge about CUREs and other inquiry-based approaches by reading this brief article, “Inquiry-Based and Research-Based Laboratory Pedagogies in Undergraduate Science” (Weaver et al., 2008). Alternatively, Anderson et al. (2011) recommend seven institutional shifts that can support curriculum change in their article “Changing the Culture of Science Education at Research Universities.”
4 Address student resource disparities	The issue of resource disparity is not new and perhaps has the longest history of intervention. Creating access and support for students occurs through a variety of avenues, including institutional financial commitments to reduce disparity for low-income students, federal and private funding agencies providing support, and political actions to reduce economic disparity nationally, statewide, and in local communities.
5 Fire the creative juices	For URM students, firing creative juices can occur by linking the work done in their STEM fields to personal and culturally valued outcomes. Brief but powerful writing exercises can be introduced into classes to help facilitate this link (see work by Judith Harackiewicz [Harackiewicz et al., 2013] on utility value exercises). Faculty, departments, and institutions are encouraged to creatively find ways to better connect URM STEM students to community-based learning opportunities or to find ways to emphasize how classroom content relates to prosocial communal outcomes. Funding agencies are encouraged to support research in STEM fields that both advances the fields and explicitly benefits vulnerable communities.

across multiple institutions. These initiatives share the aim of improving STEM outcomes for students.

FOUR ADDITIONAL RECOMMENDATIONS FOR MOVING THE SYSTEM

Capitalizing on known successes and working toward greater progress in the future, the Joint Working Group put forth four additional recommendations to increase URM persistence in STEM at the undergraduate level as mechanisms for creating force for change (see Table 1 for summary). However, the impact of these recommendations rests upon the first recommendation to evaluate successes and failures in reducing disparity at the institutional level and collect data that help provide evidence-based intervention choices by using the previously described action research approach to change.

The following recommendations draw on more than 40 years of federal and private funding and tracking of programs aimed at narrowing URM educational achievement gaps (see Table 2 for a list of programs with evidence of long term success). In some cases, these activities helped stimulate broad institutional changes that have led to marked, quantitative improvement in student outcomes, including retention in STEM fields, improvement in academic performance, and matriculation to graduate and professional schools (Okpodo and Maclin, 2009). While local efforts have resulted in some examples of institutional success, effective strategies for moving the system have not permeated the higher education landscape in a broad, lasting manner that might lead to refreezing in an improved

state. At this juncture, targeted intervention to improve URM student retention in STEM is both justified and an urgent national priority. In addition to institutional accountability, the committee found strong agreement that there is evidence that the following strategies increase URM persistence at the undergraduate and graduate levels.

Create Strategic Partnerships

To expand the impact of programs with successful outcomes, strategic partnerships should be formed between accomplished programs such as the ones cited in Table 2 (all of which have reported consistent above-average retention and/or persistence rates across many years) and programs that are (or could be) working with similar student populations. A benefit of strategic partnerships is that programs successful in increasing URM persistence can be modeled or adapted to suit institutional conditions, resources, and existing states of change. This recommendation rests on years of research showing that humans are able to accelerate learning by observing others' successes and failures (Bandura, 1977, 1986). For decades, program directors have been “learning” through a process of trial and error. However, this is no longer necessary. STEM programs that are willing to adapt their approaches can find examples on the higher education landscape of data-driven interventions that impact the individual and create institutional contexts in which students thrive. Commitment to forming strategic partnerships to ignite institutional transformation is an essential factor in improving outcomes for URM STEM students and may be the

TABLE 2. Types of programs and levels of intervention to increase URM in STEM

	Highly talented, motivated, and prepared URM students	Highly talented, motivated, but underprepared URM students
Program examples	Meyerhoff Scholars, DNIMAS Scholars (Norfolk State University Dozoretz National Institute for Mathematics and Applied Sciences) MARC/U-STAR (NIH-NIGMS Maximizing Access to Research Careers/Undergraduate Student Training in Academic Research) LA-STEM (Louisiana Science, Technology, Engineering & Mathematics) Research Scholars	SACNAS/Synapse (Society for Advancement of Chicanos and Native Americans in Science/Supporting Young Native Americans to Pursue Science Education) College Horizons Program, RISE (Research Intensive Senior Experience) Biology Scholars Program (UC Berkeley) IMSD (and NIH-NIGMS Initiative for Maximizing Student Development) NIH Women of Color Legacy Project (Spelman)
Individual-level interventions	Emphasize elite status as scholar Build science efficacy, identity as a scientist, and motivation and internalize values of STEM disciplines	Provide pre-freshman summer bridge programs, personalized academic plans and support, and preresearch training to prepare students for success.
Contextual-level interventions	Provide faculty and institutional climate of inclusion, cultural competence, acceptance, high expectations, and financial support	

Programs listed were chosen because of their national reputations for increasing retention and/or persistence of URM STEM students across several years. This list is not exhaustive.

most important factor for producing systemic change (Elrod and Kezar, 2015).

To begin the process of forming strategic partnerships, we must identify and understand successful programs, which the committee divided into two categories. As illustrated in Table 2, some successful programs have focused primarily on the highly skilled, prepared, and motivated URM students (Summers and Hrabowski, 2006; Okpodu and Maclin, 2009). Other programs have worked with a broader range of students who have motivation, interest, and talent, but do not enter undergraduate studies well prepared (Matsui *et al.*, 2003). Similar to how a doctor creates a diagnosis based on his or her knowledge or previous experience, diagnosing how to improve a program or institution's persistence rates begins with knowing the attributes of successful programs at a range of institutions, including flagship research universities, liberal arts colleges, and comprehensive state universities.

Current research has started to identify the characteristics of programs that do and do not result in short- and longer-term positive outcomes (Estrada, 2014; Linn *et al.*, 2015). The findings, largely drawn from qualitative and quantitative, theory-driven studies, identify two levels of contribution to program success: individual (person-level) and contextual (institutional/environmental) interventions. For example, program interventions that support and develop students' science efficacy, identity, motivation, and values have been found to promote persistence (Chang *et al.*, 2011; Chemers *et al.*, 2011; Syed *et al.*, 2011; Hernandez *et al.*, 2012; Graham *et al.*, 2013). One example is Spelman College in Atlanta, Georgia, whose students are URMs in gender and ethnicity, and which has been the top producer of African-American women STEM undergraduates who go on to receive science doctorates since 2008 (National Science Foundation, National Center for Science and Engineering Statistics, 2015a,b). In response to Spelman being identified as a model institution for excellence in undergraduate science and mathematics education, Thompson and Scriven (2008) have documented Spelman's successful approach to STEM education, dating back to 1972, which includes a pre-freshman summer science program, on- and off-campus research experiences

for students, and strong faculty mentoring. Encouraging students to realize their academic potential by embracing their ethnic and gender identity has resulted in more than 22% of graduates obtaining advanced STEM, medical, and allied health degrees (Jackson and Winfield, 2014).

Another example is the University of Maryland–Baltimore County Meyerhoff Scholars Program, which has found success in preparing URM students through a 14-component model that combats factors shown to compromise success in STEM among high-achieving URM students. The Meyerhoff Scholars Program includes elements such as participation in a summer bridge program, building networks of peer support, tutoring, and personal advising (Summers and Hrabowski, 2006; Lee and Harmon, 2013). A key aim of the program is to reduce student isolation and low motivation that may result from unsupportive learning environments. As a consequence of its comprehensive approach, the Meyerhoff Program has produced more than 1000 STEM undergraduates since 1989, 209 of whom have received PhDs, and 70% of whom are from URM groups.

In contrast to the Meyerhoff Program, the Biology Scholars Program (BSP) at the University of California, Berkeley, has an individualized approach that combines emphasis on reinforcing students' identity as scientists with a supportive and challenging environment of faculty and other mentors committed to student success. BSP selects students based on their passion for science, resilience, persistence, authenticity, willingness to seek and give help, and ability to restrategeize and regroup in the face of failure. Traditional measures of success, such as grade point average and Scholastic Aptitude Test scores are not determining factors. BSP reports that, over a 20-year period, their 2080 graduates included 60% URMS, 70% women, and 80% from low-income backgrounds. Across repeated studies, the retention and persistence of BSP students has been shown to be on par with (if not exceeding) rates of high-achieving students (Matsui *et al.*, 2003).

California State University, Los Angeles (Cal State LA), and San Francisco State University (SFSU), both minority-serving and comprehensive state universities, have established very successful training programs to support the development of

undergraduate and master's students committed to pursuing a PhD (Slovacek *et al.*, 2011; Hernandez *et al.*, 2012). Each program is tailored to its campus, but they share similarities. These institutions identify motivated minority talent and provide programs (Minority Opportunities in Research [MORE] at Cal State LA; Student Research Opportunities Programs [SROP] at SFSU) to develop this talent to a high level through deliberate cocurricular activities that include strong opportunities for research participation; participation in special workshops, seminars, and courses; careful academic and career advisement; and incorporation into the campus scientific community through the interaction with science faculty, academic and industrial scientists, and other successful science students. Emphasis is on student development of solid skills in the sciences, in research, and the English language in preparation for high achievement in demanding PhD programs. The Cal State LA MORE and SFSU SROP programs have together sent hundreds of students to top PhD programs nationwide, and those students have completed these doctoral programs at rates higher than national averages for all students. NSF has listed both institutions in the top 50 of U.S. institutions whose Hispanic graduates earned science PhDs. Among baccalaureate and master's institutions in the continental United States, Cal State LA is listed as number 1 (National Science Foundation, National Center for Science and Engineering Statistics, 2015a,b).

Each of the programs described focuses largely on student factors to increase persistence and graduation in STEM for talented students who otherwise may have chosen a different pathway through their undergraduate careers. According to Lewin's model of change, such individual variables are important, but insufficient, to produce a widespread improvement in the number of URM students who persist in STEM careers. A second approach of programs successful in increasing URM persistence also aims to change institutional-level variables that may impede student success, such as faculty and institutional expectations, support, departmental diversity, and climate (Anderson *et al.*, 2011; His Horse is Thunder, 2012; Slovacek *et al.*, 2012). Current initiatives have been launched with both the Meyerhoff and BSP programs to promote institutional change. Specifically, the Meyerhoff Program is being embraced and adapted for implementation at two new institutions. BSP, on the other hand, has launched a program designed to broaden its impact across its current institution. Both the Meyerhoff and BSP program expansions entail deepened institutional commitment and model how to develop strategic partnerships.

Unleash the Power of the Curriculum and Active Learning

Science education that imbues students not only with scientific factual knowledge but also the ability to use the scientific research process to promote "a lifetime of learning" is strongly needed for *all* students, but URMs in particular (Anderson *et al.*, 2011). The science curriculum—which includes course content, course sequence, discipline competencies, language, and norms—must also shift to better respond to this new age of technology, information, and rapidly advancing scientific findings. For instance, Mount Sinai School of Medicine developed a post-baccalaureate program of "systematic coaching," an intensive skills-development process to encourage persistence in biomedical careers beyond the undergraduate level (Krulwich, 2009). Several efforts, such as the Partnership in Undergraduate Life

Sciences Education (www.pulsecommunity.org), initiated through a collaborative effort between HHMI, NSF and NIGMS, and the Association of American Universities Undergraduate STEM Education Initiative (<https://stemedhub.org/groups/aau>), are advancing collective institutional efforts to implement new models for STEM curricula to respond better to technological and theoretical advances. At the level of single colleges and universities, many successful models exist to inform the efforts of peer institutions.

One of the most dramatic examples of curricular change is Harvey Mudd College located in Claremont, California. With interventions such as a restructured introductory computer science course, early exposure to research, and regular introduction to women computer science professionals, Harvey Mudd quadrupled the number of women in computer science from 10 to 40% over a 5-year period (Corbett and Hill, 2015). An important element of its success was to counteract students' feelings of being "imposters" who were not sufficiently capable of achievement in STEM fields. Harvey Mudd also modified its Introduction to Computer Science course to focus on creative problem solving, making it more attractive to students who did not have strong backgrounds in computer programming. Once engaged in the major, students were assigned summer research projects and taken to the Grace Hopper Conference for women in computer science.

Course-based undergraduate research experiences (CUREs) also are emerging as cutting-edge ways to infuse entry-level classes with hands-on research experiences for science students (Auchincloss *et al.*, 2014). While there are a variety of types of CUREs, they hold in common the placement of "authentic" research experiences in the context of undergraduate courses. There is growing evidence that CUREs result in greater retention of interest and persistence in science. Several institutions are now adopting CUREs that have been shown to be efficacious, such as the SEA-PHAGES program developed initially at the University of Pittsburgh or the Freshman Research Initiative (FRI) at the University of Texas, Austin. These types of curricular changes have been shown to impact knowledge acquisition and psychosocial outcomes and persistence for students, (Shear and Simmons, 2011; Brownell *et al.*, 2012; Alkaher and Dolan, 2014; Bangera and Brownell, 2014; Jordan *et al.*, 2014). Exposure to authentic research experiences for URMs during the academic year particularly has been shown to increase persistence (Hurtado *et al.*, 2009; Schultz *et al.*, 2011; Rodenbusch *et al.*, 2016).

Address Student Resource Disparities

There is strong evidence that URM undergraduate students are more likely than white or Asian students to come from low-income households, be first-generation college students, and experience financial strain while attending college or university (Kuh *et al.*, 2006; Cullinane and Leewater, 2009). Other evidence of financial strain is contained in the 1996 NSF report *Women, Minorities, and Persons with Disabilities in Science and Engineering* (National Science Foundation, National Center for Science and Engineering Statistics, 2015a), which reports that URM science and engineering students are more likely to come from families in poverty. The lack of financial resources hinders the ability of undergraduates to engage fully in their studies and disproportionately impacts URM students, who are overrepresented in low socioeconomic status categories. Poor students,

whether enrolled full time or part time, are more likely to work, resulting in less time to study, do internships in research laboratories, participate in STEM organizations, and attend summer STEM preparation programs. The impact of work on academic achievement, particularly work in off-campus locations, has been shown to have a deleterious impact on student performance (Thompson and Scriven, 2008). Institutions that are able to provide student financial support will produce stronger persistence and higher levels of student performance. This systemic element must not be overlooked in the universe of factors that impact the success of URM students in STEM.

We strongly encourage federal and private agencies to provide greater financial resources to low-income STEM students to reduce the significant barriers that impede URMs from fully engaging in the sciences. The inequity, of course, is embedded in the national economic landscape that exists within and beyond academic institutions, which ultimately requires action but is beyond the scope of this paper. Regardless of the source of the economic disparity, it is clear that financial strains can deeply impact URM STEM students' career trajectories. Likewise, there is also strong evidence that, even when financial resources are similar between URM and majority students, URMs are more likely to drop out of science-track educational pursuits (National Research Council, 2005). While addressing the economic disparities is essential, it is not sufficient to bridge the gap completely.

Fire Students' Creative Juices

When career scientists are informally asked to describe why they do science, quite often they describe how doing science is a creative and meaningful process for them. Current research on the adoption of academic and scientific values, whether stimulated in a classroom, an internship, work, a training program, or mentorship relationship, suggests that URM students are more likely to pursue a science career if they internalize the values of the scientific community—such as believing that it is important to work to discover knowledge using the scientific method or that scientific research can solve many of today's global challenges (Estrada *et al.*, 2011). The value of STEM skills and learning vary from person to person (values are subjective) and influence motivation to persist in an activity. Research in the learning sciences show that a person's value of a task is actually a stronger predictor of task motivation and creativity than expectancies for success (Xiang *et al.*, 2003; Wigfield *et al.*, 2009). This suggests that motivation is more likely to be sustained when the work being done is meaningful and consistent with personal (and perhaps cultural) values. On the basis of this research evidence and experience, we recommend rallying URM students around grand valued challenges of national and global significance—renewable energy, clean water, health, and climate change—that provide long-term positive contributions to society and their ethnic communities. Being invested in the research outcomes is an important factor in increasing enthusiasm for STEM academic achievement and long-term career choices. Also, providing interventions within or outside the classroom that help students connect the learning of science to held values can serve to shift interest in STEM topics.

Judith Harackiewicz's (Harackiewicz *et al.*, 2013) research has provided empirical evidence that connecting course work to a student's values can impact academic success and per-

sistence, serving as a means to ignite interest. Specifically, she randomly assigned biology undergraduates to 1) affirm personal values and later to 2) focus on the relevance and utility value of their biology course material (or not). Results showed improved course grades, semester grades, and persistence for first-generation students (relative to continuing-generation students). These results suggest that including activities that connect learning to what students value could potentially impact course selection and persistence in difficult STEM courses. One simple effective intervention, which could easily be incorporated into introductory STEM courses, is to have students write about the relevance of course topics to their own lives (Hulleman and Harackiewicz, 2009; Hulleman *et al.*, 2010). The use of undergraduate research experiences (UREs), which commonly occur outside the classroom, stimulates students' sense of discovery and appears to impact cognitive gains and contribute to greater retention (Laursen *et al.*, 2010; Lopatto and Tobias, 2010). Future research is still needed to verify whether ignited creativity and meaning mediate these outcomes, but anecdotal evidence suggests this hypothesis deserves future study.

There is a plethora of methods for igniting the creative juices of students, but for URM students, it may be particularly important that collectivistic values (common to Latino, Native American, and African-American cultures), which emphasize actions that benefit their communities, are favored over more individualistic cultural values that celebrate individual success and accomplishment (Triandis, 1993). More recent research on communal goals has shown that URM students in STEM more highly endorse communal goals (Smith *et al.*, 2014; Thoman *et al.*, 2015). And there is increasing evidence that URM motivation and persistence in STEM fields must address cultural issues such that the goals of STEM fields are more congruent with student prosocial goals (shaped by their cultural experiences; Allen *et al.*, 2015). Further, research on communal goal affirmation provides empirical evidence that URMs and women are more likely to engage in science for altruistic reasons and in pursuit of valued social causes (Seymour and Hewitt, 1994; Miller *et al.*, 2000). Ultimately, successful STEM professionals are those who find their work satisfies creative needs and adds meaning, which occurs when a student connects scientific discovery with what really matters given their life and cultural experiences.

SUMMARY

While the members of the NIGMS–HHMI Joint Working Group come from many different disciplines and bring with them a diversity of academic institutional experiences, the committee has wide consensus regarding the recommendations for moving STEM disciplines toward broader participation. Understood within the theoretical framework of Kurt Lewin (1946), the recommendations provide a map for 1) how to better evaluate the state of institutions and track progress, resulting in greater institutional accountability; and 2) how to better use existing knowledge and experiences to iteratively diagnose and create a plan of action to move the system through creating strategic partnerships, unleashing the power of the curriculum, addressing student resource disparities, and firing students' creative juices to sustain progress in STEM. For moving the academic system through reducing disparity and capitalizing on the

strengths of the ethnic diversity of the U.S. population (using an action research approach), two guiding principles are recommended. First, *build on what works*. All members of the advisory group touted the fact that we have examples of programs that are exceptionally effective at supporting URM persistence in STEM and that the characteristics of those programs that create “lift” for URM STEM students must continue to be systematically identified, empirically tested, and widely applied across science programs nationwide. At this time, successful programs are defined by both national reputation and evidence that the retention and/or persistence rates of students consistently exceed the average for that department, school, university, or nation.

Second, *be guided by data, proven theory, and effective practice*. Effective programs and approaches will gain the greatest momentum if we can see the amount of progress or disparity that exists at the institutional level, both quantitatively and qualitatively. Likewise, at the program level, successes and failures in specific interventions should continue to be rigorously assessed using behavioral and social science research designs, and refined as needed, based on evidence. Future research on activities that involve program adaptations, curricular reform, reducing economic disparity, and igniting greater “fire” should include the following when possible: 1) comparison groups; 2) prospective, longitudinal tracking of short-, medium-, and long-term impacts; 3) large enough sample sizes to draw statistical conclusions (achieved through collecting similar data across multiple institutions or like programs when possible); and 4) collection of information that both tracks important outcomes (such as retention and persistence) and helps us to understand *why* these outcomes occurred.

The committee of experts on URM education in STEM fields concluded that, when institutions, science educators, and funders commit to these five recommendations (guided by the two basic principles just described), the system will move positively and significantly toward accomplishing increased equity and better celebrate the successes of institutions that achieve parity. Through innovation and creation of supportive environments that are excellent and inclusive, all students will garner greater lift and thrive.

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