Developing Talent to Increase Diversity in Biomedical Sciences Workforce: Introduction to Fourth Article in Feature Series
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The article by Anne MacLachlan in this issue of the *Mount Sinai Journal of Medicine* is the final article in a series of four articles whose theme is increasing diversity of the biomedical-sciences workforce. Dr. MacLachlan considers "building blocks" that constitute an effective undergraduate diversity program and how the design and execution of the program elements match the range of challenges confronting the particular students in the program. The article provides an overview of key issues that need to be considered for program design and execution. It also presents examples of successful programs, outlining important contributors to their success.

SPECIAL FEATURE

Minority Undergraduate Programs Intended to Increase Participation in Biomedical Careers

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OUTLINE

ABSTRACT

This article reviews a selection of undergraduate programs intended to increase successful minority participation in science, technology, engineering, and mathematics majors, potentially leading to biomedical careers. The object is to examine their structure, consider how well they address the issues of the target population, and assess the extent to which they have met/meet their goals. As a means of conducting this review, the first step is to examine the concepts used as the building blocks for program design. These concepts are found in a shared, yet often undefined, vocabulary used in most undergraduate programs for minority students. The hypothesis is that a shared vocabulary obscures a broad range of meaning and interpretation that has serious ramifications affecting student success. How these building blocks are understood and implemented strongly reflects the institution where the program is housed. The discussion further considers the nature of a number of programs created by the National Science Foundation and the National Institutes of Health specifically for underrepresented minority students and examines one program in detail, the University of California Berkeley's National Science Foundation Research Experience for Undergraduates Program in Molecular, Cell, and Evolutionary Biology.

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The characteristics of federally organized programs and the Research Experience for Undergraduates are contrasted with 2 very successful student-centered local programs based on a different conceptual model. ***Mt Sinai J Med 79:769–781, 2012.***

Key Words: biomedical careers, mentoring, minority participation, undergraduate minority programs, undergraduate research experiences.

Although considered generally successful in attracting and training students in science, technology, engineering, and mathematics (STEM) fields, federally mandated and funded programs targeting minorities have been found less successful in transforming minority participation in STEM into the biomedical pipeline. They have been under review and discussion for several years.[1–5] Over recent decades, these programs have done a great deal for many students and greatly assisted them onto the path of becoming a research scientist by enabling them to graduate from college and enter graduate programs at a higher rate.[1,5] The sources of dissatisfaction expressed in the 2005 Committee for the Assessment of the National Institutes of Health (NIH) Minority Research Training Programs report[3] and others derive from overly ambitious goals to change the ethnic and gender composition of the biomedical workforce and a lack of definite knowledge about the overall impact of any particular program. A particular source of dissatisfaction is the large falloff between STEM bachelor of science degree (BS) attainment for students of color and enrollment and completion of doctoral programs (PhD). In 2009, 13,214 domestic US minority students earned a BS in biology, with women earning 8832 (66.8%) compared with 4382 (33.1%) earned by men.[6] In the same year, only a total of 541 US domestic minorities earned PhDs in biological sciences: 232 Blacks (of which 166 71.5% were female), 282 Hispanics (of which 151 [53.5%] were female), and 27 Native Americans (of which 12 [44.4%] were female).[6] How many of these PhDs had previously participated in undergraduate programs is largely unknown, because this has not been a question on the National Science Foundation (NSF) National Center for Science and Engineering Statistics' Survey of Earned Doctorates.[7] Additionally, too few undergraduate programs have been evaluated or assessed; for those that have been, the evaluation is local and not shared in a way that could contribute to broader knowledge. The critical difference is that for all US-citizen and permanent-resident BS recipients in biology, 6.7% earned a PhD, whereas only 4% of US domestic-minority BS recipients did so.[6,8]

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This long-term phenomenon cannot be explained–perhaps because evaluation tends to focus on the immediate impact of a research program without consideration of all the elements the student brings to the program. A particular program's impact, or lack of it, could be related to issues external to the program itself. Bright students in any academic setting are sometimes not as successful as could be expected–not because of a program or curriculum, but because of changing personal interests, uncertain career goals, or difficulties arising from their economic situation.[9]

The concern about minority achievement in STEM through undergraduate programs is now exacerbated because of a growing lack of interest in science fields generally on the part of American undergraduates. Although there has been a series of programs for curricular reform, particularly since the 1997 appearance of Seymour and Hewitt's *Thinking About Leaving*,[10] it is taking on an urgency expressed in new programs calling for institution-wide STEM curricular reform and support enhancement, such as the NSF's Widening Implementation and Demonstration of Evidence-based reforms (WIDER)[11] and a Howard Hughes Medical Institute (HHMI) launched in May 2012 a fifty million dollar initiative on multiple aspects of science teaching. Howard Hughes Medical Institute. Grants for Baccalaureate and Master's Granting Colleges and Universities: Program Announcement. http://www.hhmi.org/grants/pdf/comp_annc/2012 colleges.pdf accessed October 31, 2012. The National Academies have produced several reports on the coming shortage of US scientists and engineers, with an emphasis on the underutilization of people

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of color and women. The reports carry increasingly alarming titles, moving from *Rising Above the Gathering Storm* (2007)[12] to *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5* (2010)[13] and *America's Science and Technology Talent at the Crossroads* (2011),[14] including an earlier report on racial discrimination (2004).[15]

While all this is taking place at a high level of policy remote from the daily life of an undergraduate, students, including those of color, see opportunity shrinking. Even before the economic downturn it was recognized that community colleges had substantial work to execute before becoming a major source of minority STEM students. Community colleges, which enrolled 40% of the 19-million+ US undergraduates in 2012,[16] are rationing enrollment (in California, 472,349 students are currently on waiting lists for classes), reducing student services, and cutting faculty so that STEM courses for transfer are oversubscribed and less academic support is available.[17] As it is, despite having the largest minority enrollment of any higher-education institution, few minority students transfer in STEM. In 2008, when California enrolled 43% of all community-college students nationally, only 54 African Americans and 262 Latinos statewide transferred in STEM to the University of California (UC). In the same year, statewide transfer in STEM to the California State University system included 113 African Americans and 642 Latinos.[18]

At four-year institutions, tuition is rising, admissions are increasingly competitive, and students are expected to finish their degree in the shortest feasible time. If graduate school in biomedical fields is on the student's horizon, significant undergraduate research is now pretty much mandatory for admission, adding yet another time-consuming requirement. In addition to these pressures, students of color see very few faculty who look like them or share their life's experience. They are also likely to experience predominantly white colleges with a smattering of perceived small racist insults, reminders that they are still to some extent outsiders.[19,20] Moreover, most students at four-year colleges and universities who are working in laboratories perceive graduate students, postdoctoral scholars, and faculty working long hours under substantial time and achievement pressures. For some, this view of scientific life can have a negative effect on graduate-school aspirations.[21]

So students of color as well as others see a highly contradictory world. Exhorted by family and society to go to college, they work hard in high school to get admitted and enter a demanding curriculum in STEM with increasing subject areas required in biology beyond calculus and organic chemistry. Because college costs at public institutions increased 42% between 2001 and the 2010–2011 academic year to an average of $20,100 ($39,800 for private institutions), students likely absorb a large amount of their parents' money or go into substantial debt.[16,22] At the same time, students may well wonder if it is worth it in a society that does not necessarily value the presence of people of color in a professional setting.[3,20] These are the students who attend reasonable high schools and likely have middle-class parents supportive of academic achievement. Young people of color, though, are more likely not to have these advantages because they are part of a much larger group that is marginalized socially, educationally, and economically. Against a national average of 75.5%, a lower percentage of Blacks and Latinos graduate from high school at all.[23] In California in 2010–2011, only 63% of African Americans and 70.4% of Latinos graduated from high school.[24] Even if close to half of those dropping out later earn a GED, that usually does not lead to four-year college enrollment.[23] The achievement gap between members of the African American and Latino middle class and their working-class counterparts is great, but not so great as the difference between the white and Asian middle class and all classes of minorities.

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FEDERAL PROGRAMS

Federal programs cover a range of organizational forms reflecting different strategies for broadening STEM inclusion. For example, the NIH Bridges to the Baccalaureate Program (Bridges) began in 1992 with the express purpose "to make available to the biomedical research enterprise and the nation the intellectual talents of an increasing number of underrepresented minorities."[3] The Louis Stokes Alliances for Minority Participation (LSAMP) "was established by Congressional mandate in 1991 to significantly increase the quality and quantity of minority students who successfully complete baccalaureate degrees in [...] STEM and who continue to graduate studies in these fields."[25] It has been very successful in doing so.[26] When these programs were created, the legal and political/social climate supported these goals. Up to 2012 there have been numerous challenges to minority educational programs, but their legal basis at the federal level is still anchored in a range of

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current law, including the Higher Education Act of 1965, as amended, Title III, Part E, Subpart 1 for Department of Education Programs.[27] Other agency programs in NSF and NIH are supported by a range of law and legislative action, but all are subject to narrow scrutiny in a political climate often hostile to such programs.

In the course of the past decades, separate programs were created for Minority-Serving Institutions and for Predominantly White Institutions, although programs may link these 2 types and also incorporate high schools and community colleges. Also separated are "workforce-development programs," such as those found in biotechnology at community colleges and high schools. The sheer complexity and number of programs for STEM inclusion make it difficult to either acquire an overview or easily understand what they all are doing, particularly if privately funded or institution-based programs are included. For this assessment, the programs discussed are a only a small sampling of federally funded minority programs at the undergraduate level operating in predominantly white four-year institutions, along with 2 local programs.

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They are already attending college, they have already completed some of the basic science courses, and they have done so usually while attaining at least a 3.0 grade point average (GPA). Program admission also requires strong letters of recommendation and a convincingly expressed interest in science/scientific research on the part of the student. In many contexts, this has been referred to as "skimming" or "cherry picking."[4] Yet without these attributes, the likelihood of the student intellectually profiting from the program may be limited. The actual requirements are usually set out in the Request for Proposals (RFP) as guidelines, interpreted by the principal investigator (PI) to suit the program and local circumstances. Depending on the PI, the requirements can be flexible or stringent. The PI is the link, the connection, the nexus between national policy as reflected in the RFP and the individual student. Consequently, the PI's understanding of what he or she is doing is critical to the success of the student. This is where understanding of the concepts employed in defining the program and its activities is critical.

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SHARED CONCEPTS

Although usually not expressed in the title of the program RFP, the idea of increasing the number of minority students is to promote "diversity" in the STEM or biomedical workforce. The term has lost a clear focus and has come to mean a mix of individuals in any academic setting from many different ethnic, cultural, and economic backgrounds.[28,29] It hangs together with the concept "minority" and who the PI understands belongs to this category. "Diversity" is also a useful term for those who would like to distance themselves from affirmative action programs that were specifically designed to increase domestic US populations earning college degrees.[28,30] "Promoting diversity" has therefore come to mean a great variety of programs at the undergraduate level that were originally intended to increase postsecondary participation of those from "disadvantaged" backgrounds. This can include members of a traditional domestic minority group such as African American, Chicano/Latino, or Native American, coming from uneducated and usually poor families–a condition that heavily overlaps with domestic minority status–women of any ethnicity in male-dominated fields such as geoscience or engineering, or those with disabilities. In practice, however, participation in diversity programs has often been expanded to include a large number of immigrants, white women, and those from middle-class backgrounds.[21,28,29,31–33]

In itself it is a good thing that all students with an interest and appropriate academic preparation have an opportunity to participate in programs that may intensify their commitment to a scientific career. But minority programs were created specifically to overcome the gap in higher-education access, achievement, and degree completion between majority and minority populations. The result is that participation in such programs by students of all backgrounds tends to displace those for whom

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several of the programs were designed: domestic first-generation minority students. It is a problem

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on several counts: All students are not the same, and first-generation students of color are likely to have concerns and face challenges not experienced by more privileged majority and immigrant populations. This may affect their self-confidence, their sense of identity ("Do I see myself as a scientist in the making?"), their comfort in a laboratory or at a research university, and their sense of belonging. Moreover, all minority students are far from the same, so it is important that they receive mentoring sensitive to their culture and concerns. This is not suggesting that laboratory directors, PIs, and others involved in any particular program become sociologists or counselors, but that they develop a deeper awareness of how a student's culture/background can affect their academic performance. Because we do not know why there is such a large dropoff rate between a earning a BS and earning a PhD for students of color, actual experience as an undergraduate could potentially be a reason. It is one of the many areas where far more, and more qualitative, research is needed.

To expand on the complexity of diversity, it is instructive to look at the concept of "minority." The term has fallen out of favor because of its ambiguity and the implication that a member of this group is somehow perpetually on the outside, apart from the majority.[34] Apart from groups sometimes defined in an RFP today such as African Americans, Native Americans, Hispanics, and Pacific Islanders, targeted populations are expanded to include first in their family to attend college, from various forms of "disadvantaged". Examples include but are not limited to NSF programs such as the Research Experience for Undergraduates, (Placeholder1) and the NSF Louis Stokes Alliance for Minority Participation. (Placeholder2) Also included are the National Institutes of Health Bridges to the Baccalaureate (Placeholder3) and Doctorate, (Placeholder4) and the Department of Education Trio Programs, particularly the Ronald E. Mc Nair Program (Placeholder5)

Placeholder 1: National Science Foundation Research Experience for Undergraduates Program Solicitation http:/www.nsf.gov/pubs/2012/nsf12569/nsf12569.pdf accessed August 2, 2012

Placeholder 2 National Science Foundation Louis Stokes Alliance for Minority Participation Program Solicitation http://www.nsf.gov/pubs/2012/nsf2564/nsf12564.pdf accessed August 27, 2012

Placeholder 3 http://grants.nih.gov/grants/guide/pa-files/PAR-12-277.html accessed September 10, 2012

Placeholder 4 http://grants.nih.gov/grants/guide/pa-files/PAR-12-276.html accessed September 10, 2012

Placeholder 5 Department of Education Office of Postsecondary Education, Ronald E. McNair Postbaccalaureate Achievement Program. http://www2.ed.gov/programs/triomcnair/index.html accessed October 30, 2012

Students applying to programs are usually free to define themselves as belonging to a particular ethnic group. Thus, students of mixed race don't know what box to check (although African Americans still seem to follow the Jim Crow "one drop" rule) or are difficult to categorize if they can check all boxes that apply.[35] Immigrants with citizenship or green cards are likely to check the appropriate general category: African American if they come from Africa or the Caribbean, and Latino or Hispanic if they come from anywhere in Latin America or the Iberian Peninsula.[29,32,36] White students have been observed by the author to also check ethnic boxes for distant relatives, such as Native American or African American. Are all these people really minorities? Who is really being counted here? More significantly, the college-age cohort in the United States is close to 50% "mixed race."[37] All of this suggests that ethnic categories are not helpful in an age of mixed race or claiming ethnicity for the affirmative action advantage, even though it no longer exists. That is not to say that individuals do not suffer real discrimination if they are taken by others to appear "minority" because of their physical appearance. Existing categories also deny the intense ethnic identities and cultures found among the highly diverse Hispanic population.[38] In the future, it might be more useful not to ask what an applicant "is," but with which cultural/ethnic community he or she identifies. As it stands, data on ethnicity are not very trustworthy.

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Most efforts to encourage students to pursue a biomedical pathway are centered on direct research in a laboratory "under the assumption that actively engaging students in research and related activities will stimulate their interest in and understanding of science and encourage them to pursue research careers."[2] This assumption is supported by the ubiquity of research within minority programs. There is a growing body of literature, particularly since the founding of the Council on Undergraduate Research in 1978, and further stimulated by the publication of the Boyer Commission Report in 1998, that argues for the central role of research in solidifying student aspiration.[39] The use of research seems to be well grounded but embodies an implicit assumption that the character of "research" will be more than laboratory maintenance or learning procedures, and instead will be an intrinsically interesting problem that captures the student's imagination. This is not always the case.[40] It is further anticipated that this activity will confirm or generate a desire to obtain a PhD, although some students do not pursue a PhD or learn they do not like research.[31,41,42] This comes back to the issue of a shared vocabulary, but not necessarily a shared understanding that has the potential for affecting student interest and success. The character of the project the student is working on is the first issue related to research. The second issue, however, is the laboratory itself. In the execution of research in a laboratory, students enter a small social system in which the way the laboratory is run affects morale. Acceptance into this society is important for building student confidence and stimulating learning. It relies on the PI for setting the tone within the laboratory about how the student is to be initiated. In short, "doing research" is a complicated set of interactions made even more complicated if the entering undergraduate is different from the other laboratory members or may need more direction about laboratory behaviors and norms.

The central concept to doing research in undergraduate programs is that of mentoring. Mentoring is the process by which a student is guided to an appropriate academic level to be an effective researcher and supported in developing a passion for research while having his or her horizons expanded and feeling supported. Mentoring is believed to be absolutely critical in the development of student talent, and it is, but the actual form it takes–or whether it takes place at all within a specific program–is not straightforward.[3,43,44] That it can be problematic is certainly recognized, as a recent article in *Nature* makes vividly clear from the responses of 800 faculty members.[45] Behaviors that are not seen by faculty as serious are often demoralizing for doctoral students, such as not turning up for appointments, having student favorites, ignoring students with interests different from their own, or not providing feedback.[45] In the assessment conducted by the National Academies in 2005, NIH came to a similar conclusion.[3] Significantly, mentoring studies on undergraduates are hard to find.

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Although the formal charge by the funding organizations is that the PI is the student mentor, in practice graduate students and postdoctoral scholars function as the actual mentors some–if not much–of the time, particularly at research universities.[21,41] This is not necessarily a bad thing at all, as graduate students and postdoctoral scholars are usually in the laboratory every day and do not have the intense set of commitments of a PI at a research-intensive university. Usually they have the patience of those not so far removed from their own introduction to research, and they acquire teaching and mentoring skills in the process. But it is all too likely a process without direction, although the programmatic expectation is that faculty mentor students in the program. But whether it is a faculty member or not, usually no significant training in mentorship is provided at any level, nor is it usually a requirement within the mandated program structure, although training is available.[44] It is an activity that most scientists believe they understand implicitly along with the funding agencies, yet is not sufficiently scrutinized.

Mentorship training is particularly important because of the ethnicity, gender, and economic background of students targeted in minority programs that may differ substantially from the person in the mentor role. There appears to be a tacit understanding that faculty know or should know how to effectively mentor a young person beginning scientific research

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from their own training and experience as scientists. Indeed, generations of white-male faculty have successfully mentored every kind of student. Perhaps for this reason, issues of implicit bias, favoritism, and negative mentoring are not usually considered in relation to undergraduate mentees, but emerge more in the literature about doctoral training and in connection with new faculty of color, particularly women of color.[3,46,47] It is legitimate to ask why these characteristics are not considered in relation to young people who may lack confidence in their academic abilities, no matter how high their GPA, and who feel alien in an academic environment in which language, forms of social interaction, general knowledge, and a host of things large and small can make the student feel very different from those in the laboratory, and very different particularly from his or her assigned mentor. Mentors who are insensitive to the culture and background of students and focus purely on science may not be providing the kind of support a student needs, even if statistical studies suggest that mixed mentoring by race and gender has no statistically significant negative effect and possibly a slightly benign effect.[31] Like it or not, as an example, an African American mentor interacting with an African American student is more likely to acknowledge the challenges such a student faces and provide an implicit scaffolding of support and encouragement critical to developing that student's self-reliance and confidence as a future scientist.

The absence of minority faculty at majority white colleges and universities where many "minority" programs are located possibly may be another reason why careers in science are not very attractive to students of color.[3] They do not see faculty who resemble them, and they also may not get the cultural acknowledgement and support that bolsters their scientific achievement. Again, this is an area inadequately researched. A highly suggestive anecdote illustrates this particular issue. In the biology department at San Francisco State University (SFSU), 33% of faculty members are minority, including Latino/as, African Americans, and a Native American, out of a total of 45 from many other cultures in the department. The biology department hosts many undergraduate minority programs: NIH Bridges with San Francisco City College; Minority Biomedical Research Support–Research Initiative for Scientific Enhancement (MBRS-RISE) Program and Minority Access to Research Careers (MARC); NSF Research Experience for Undergraduates (REU); the LSAMP, and others. As part of the department's strategy to support minority students, students in these programs were asked to select minority scientists for a seminar series. The students responded that they would much prefer to invite speakers on the basis of their science, because they had plenty of role models in the department itself. Apart from clearly making program students feel comfortable in the department, it raises the question whether more students from SFSU go on to graduate school and finish than students in programs in other institutions with few or no minority faculty. How much does the overall academic environment contribute to a program's success? In an institution like SFSU that takes teaching seriously and where the biology department is deeply committed to student and minority student success, it is likely that students of color go on to graduate in greater numbers.[48] Indeed, in information provided by the department chair, Carmen Domingo, since 2005, 30 minority students at SFSU from NIH-funded training programs have received PhDs in biomedical fields, and another 103 are currently enrolled in doctoral programs.[4] Again, however, a comparative study is necessary.

Mentoring is closely connected to helping a student develop "self-efficacy." This concept was developed by Alfred Bandura in 1977 and continues to be explored.[49,50] It has come to be the leading idea in program RFPs and is used as a shorthand for students turning themselves into effective junior scientists. The concept speaks to developing normative successful academic behavior, effective learning strategies, discipline, and dedication. It has been further expanded by Martin Chemers to include leadership and community involvement, meaning involvement in the science community.[51] There is no denying that self-efficacy is a useful concept, and it has been adopted by the STEM community broadly. But as modified by Chemers, it still does not recognize that, generally, minority students in the various research projects developed within undergraduate programs who validate the idea of self-efficacy are preselected, as there is a clear threshold for admission to college and into these programs. Even membership in an organization such as the Society for Advancement of Chicanos and Native Americans in Science (SACNAS), from which he draws his sample in one study, shows a measure of entrepreneurship or another form of self-efficacy. There is a selection bias. If students are not asked questions about the rest of their identity in relation to their cultural background, their thoughts in this area are invisible. So it is not surprising that self-efficacy is not without its critics who think that the concept needs expansion to understand how and why a student of color comes to identify with the scientific community, and, in so doing, persists in it.

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Estrada-Hollenbeck *et al* have drawn on a spectrum of theorists to elaborate a differentiated model tested in a longitudinal study of 1800 African American and Latino students that emphasizes how undergraduate students respond to science as a social system.[52] What recommends their model beyond self-efficacy is that it addresses the complexities of being a student of color beyond being academically proficient and emphasizes the interactive nature of the scientific socialization process. This seems to be a promising avenue to explore why fewer students of color persist into graduate or professional school. It also draws attention to the fact that students in a particular program are participating in a series of social interactions that are not limited to interacting with the mentor.

Self-efficacy also allows little room for the real consequences of being from a poor background and the attitudes and behaviors that often accompany low socioeconomic status, whether in combination with minority status or not. Students from such a background are likely to have been exposed to a life of uncertainty. They may be academically accomplished but hindered by nonacademic constraints. Shame about one's poverty can have effects unanticipated by any program coordinator. In an illustrative anecdote, shame kept a very talented student in a state minority program from presenting an abstract because he only had one pair of (shabby) shoes and did not want to admit it. (New shoes were provided, and he gave a great presentation.) This degree of poverty is not likely to be thought about as an obstacle to student progress in relatively affluent white institutions, and questions about poverty are not usually asked–financial resources do not capture the sting of it.

NATIONAL SCIENCE FOUNDATION PROGRAM: RESEARCH EXPERIENCES FOR UNDERGRADUATES IN MOLECULAR, CELL, AND EVOLUTIONARY BIOLOGY

How these elements play out in practice can be seen in a closer examination of the summer National Science Foundation Research Experience for Undergraduates Program in Molecular, Cell, and Evolutionary Biology at UC Berkeley that the author co-organizes and evaluates (ie, the BIO REU, or biology REU). All the factors discussed come together in every undergraduate minority program, but their impact may be intensified because of the intensity and relative shortness of these programs. Knowledge about the program derives from ongoing internal evaluation, observation, and an as-yet-unpublished survey analysis in which all current biology REU programs participate.[21,53] Nationally there are more than 600 sites in all science and engineering fields. The Berkeley summer REU in biology has been in place for 7 years and is one of 28 such programs nationally. Every year the program has hosted from 10 to 13 students, with 1 or 2 of them most years funded by the MARC program from their home institution. To date the program has enrolled 80 students.

Student participants have been highly diverse ethnically, come from different types of colleges and universities as well as from different parts of the country, and include a few green card–holders from other countries. Student ages and year in college are fairly similar, largely juniors and seniors. All students conduct 10-week research projects, working 40 hours a week in a Berkeley laboratory under their PI and often a designated co-mentor, concluding the summer with a PowerPoint presentation. This is accompanied by weekly professional-development sessions and a weekly research seminar. The students are made to feel welcome at Berkeley. They are picked up from the airport, housed in International House, provided a unique orientation and ice-breaking session on their first full day, and receive Berkeley IDs along with a good stipend. They are taken on field trips in the area and to scientific facilities in and around Berkeley. At a dinner for the students held at the conclusion of the summer program, each receives a certificate of participation.

Students enter with what is believed to be the academic proficiency to profit from the research experience. For some it is not their first research program, so they tend to be able to move more quickly. Those without prior experience also immerse themselves in the work, and most students are observably engaged with what they are working on. A few students have turned out not to have the necessary background for the level of expected work. In an atypical, but interesting, case, a younger woman was particularly discouraged because she did not understand the vocabulary of biology. Family support really mattered in this situation. Her mother came out from the East Coast to give her a pep talk about not wasting a wonderful opportunity that would help her greatly with her ambition to become an MD. It worked. The young woman applied herself diligently to acquiring the appropriate vocabulary (it meant also understanding the nature of the process or organism) and finished with an acceptable presentation. She went on to earn her MD.

Adjustment problems related to being at Berkeley, as well as leaving home for the first time, were found in students every year. A significant factor in helping these students were the other students in the program, who encouraged and supported one another and during the summer often formed a definite community of friends sustained years after leaving Berkeley. There have been loners, cliques, lack of integration of students already living in the Bay Area, and a couple of dominant personalities, but group dynamics functions fairly effectively. A big part of the positive evaluation of the program has to do with mutual support and group cohesion.

A significant factor in helping students enrolled in minority research programs are the other students in the program.

A positive evaluation from the perspective of the organizers is the large number of students who entered PhD or professional doctoral programs, or who found their life's passion in biology-related work with their BS. Seven of 12 from year 1 (2006) are in PhD programs (1 finished this year); 1 has finished medical school. Another of the remaining 4 plans to go to medical school next year. The pattern in subsequent years is somewhat similar–students more often work in a biology-related field after earning their BS, clarify their interests, and decide to go to either graduate school or medical school. From year 2 (2007, with 10 students), 5 are in PhD programs and 1 is in medical school.

Program participation has been helpful to students in ways other than academically. Most of the students are students of color. An unanticipated issue arising for these students, and a question not visible in the literature as far as can be ascertained, is: What is it like to belong to a "minority" program as a student of color, such as the Berkeley REU? Yet for some students, this has been an important issue, significant for their adult development, their commitment to science, and, for some, a commitment to their community. There have been a number of students over the years who hardly ever identified as a "minority." Some of them grew up in Spanish-speaking, Latino-dominated environments, came from an African American area of the South and attended a historically black college or university, or did not appear particularly "minority" and were usually taken as white. The evolution of self-identity seemed to be a significant contribution of the program as various individuals took different paths to understanding who they are personally and who they are in relation to others. This path did not stop when the program ended. As far as can be observed from this sample of 80 students, acquiring greater clarity about one's identity generally goes hand-in-hand with clarity about pursuing science as a career. It is important to remember that most undergraduate students are still young, clustering in this program between the ages of 19 and 24. No matter what their background, in their program evaluations the majority of students characterize the Berkeley BIO REU as "transformational," solidifying their identity by integrating their interest in science with all else that they are, increasing their commitment to graduate school or medical school, or helping them realize that this is not the path for them. The impact of occasional behaviors described as racist by participating students of color did not seem to have been direct or immediate, as reported in exit interviews.

The internal evaluation for the Berkeley BIO REU was partially modeled on David Lopatto's pioneering national survey of summer research programs so that results could be compared with his.[41] The survey is useful generally to understand a part of what students have learned, the contribution of the program to their scientific self-confidence, and how they experienced the program. More subjective and nuanced information is acquired through discussion with students, exit interviews, and observation. Student feedback suggests that they get much more out of a program like this than they would if they conducted their research without a unifying program building cohesion among participants, providing broader intellectual background or professional development.

REAL COST OF EXPANDING PARTICIPATION

Because college-level programs involve populations who are prescreened, it is instructive to look at a Bay Area high school program housed in the Bayer Corporation facility in Emeryville that works with students who would be unlikely to attend college or possibly even graduate from high school. It is a high school–to-college or employment program, utilizing laboratory work in biotech. Called Biotech Partners,[54] it provides insight into what is really involved if a program wishes to develop disadvantaged young people of color whose talent for science

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may not yet be demonstrated. The program takes as its point of departure that there is substantial intelligence and talent among the students in high school who may be limping along with a GPA of 2.0 or lower while possibly engaging in self-destructive or antisocial behaviors. These are students who, if left alone, may never graduate from high school. The program recruits students in the 10th grade by providing extensive information about the benefits of the program through all possible people touching a student's life: teachers, counselors, school administrators, program staff, and outreach to families. Seniors in the program also speak in all sophomore classes for 10 minutes about their experience: the paid internships, skill mastery, professional training, provision of all necessary services to succeed in high school and college, performing technical work, building academic and social self-confidence, and preparing for college entry. The first step is that interested students apply.

The program is holistic and involves a heavy commitment on the part of the student and the student's family. It takes into consideration all impediments to success. On occasion these have included groceries, clothing, even housing. Home support is necessary for success, so there is outreach to parents to engage them in their child's success. Indeed, in order for the student to participate, both student and parents sign a detailed commitment that requires official documentation of low-income status. It is an intensive program with a year-long biotech class in the junior year conducted 1 hour a day side-by-side with job-training activities: résumé writing, mock interviews, "dress for success," tutoring, study skills, and goal-setting. In summer, the student works at a paid internship for one of the sponsoring companies. The program continues into the senior year with advanced biotech, college information and application assistance, applying for financial aid, informational college visits, and all other services/activities as necessary. It is comprehensive throughout these 2 years.

The outcome is impressive: In the last 5 years, all of the 200 students who persisted in the program graduated from high school.[54] Internal evaluation material from Biotech Partners shows that in the last the last 3 years 80 graduates have gone on to mostly 4 year colleges and universities, the rest have been hired at the companies where they interned such as Bayer, Novartis, and other partners, or work at national labs, USDA and elswhere. All are either employed or at college. Supporting companies sometimes will pay for program participants to complete a four-year degree. These are students who usually are the first in their families to earn a high school diploma. It is a program of transformation, broadening educational participation to a group of students otherwise likely to be left behind. Unlike other programs, it works with young people of promise who would not qualify for the Mathematics Engineering Science Achievement (MESA) program or joint high school/college enrollment, or the many local college outreach programs in Bay Area high schools. Like nothing else, it truly makes it possible for low-income students of color to enter the world of biomedical professional employment, where there are many available well-paying jobs.[55,56] At the same time it is a concerted community effort of 2 high schools, a couple of community colleges, and a staff of 7 at Biotech Partners, as well as teachers, counselors, and mentors, to work closely with student participants and their families. Its relevance to this discussion of undergraduate minority programs is that it makes the point that programs within four-year institutions can only reinforce or perhaps even generate a commitment to a STEM major because the population is already preselected. For the outflow from the "pipeline" at the PhD level to be commensurate with the desired outcome of a truly diverse biomedical workforce, much more attention needs to be given to lower grade levels to develop talent, not just harvest talent. Programs such as MESA or the Meyerhoff Scholars Program at the University of Maryland, Baltimore County do much for keeping high school students on track into and through college, but they also work with those who are capable of attaining a 3.0 GPA. As the Biotech Partners program makes clear, truly expanding college-ready populations from those not on track is time-consuming, intrusive, costly, and essentially requires a village–the entire gamut of school personnel, families, and, not least, the companies that support the program and provide paid and instructive internships.[57,58]

A program with a related perspective, but within the already select community of UC Berkeley undergraduates, is the Biology Scholars Program (BSP). Information about it comes from a part of a grant application prepared by the BSP Director, Dr. John Matsui. Initiated with an HHMI grant in 1992, it recruits low-income minority students who are the first generation in their families to attend college and have entrance qualifications to UC Berkeley slightly lower than those of the primary applicant pool. To be admitted, a student has to demonstrate a passion for science, a facility to overcome challenges, and a willingness to commit to serve others. There is no GPA threshold. A major structural aspect of the program is that upperclassmen who have already profited from the program work with younger program students as tutors and coaches, offering support and encouragement.

The emphasis is on science and academic success. Every fall, the director teaches a freshman course in which he explains and demystifies the university concepts of departments, majors, laboratory groups, grants, tenure, research, and peer-reviewed journals to help new program participants learn the language, customs, organizations, and practices of university science. In spring, he teaches "Public Understanding of Science." Students usually remain in the program until graduation, and specific career advising is available for the PhD and MD track and for many other areas. The success of the program is that participants graduate with GPAs as high as their UC majority classmates and in the same percentages. The program has supported 2650 Berkeley undergraduates in the past 20 years; 80% are first-generation and/or low-income, 70% are women, and 60% are under-represented minorities. Between 2004 and 2011, 85% of BSP students who applied to medical school were admitted, compared with a national average of 50% and a UC Berkeley average of 55%. The achievements are truly spectacular, as BSP students have earned hundreds of advanced degrees in many fields. This is possible because the program addresses the needs of those sometimes described as "not Berkeley material," working with potential rather than prior achievement. It provides both the technical and moral support necessary for student success. It is a large program and is expensive, but it employs many people, including its own members, as tutors, coaches, and staff, and has a low cost per individual student member. Its impact is broad and deep.

CONCLUSION

In conclusion, this review of a limited number of generally successful minority STEM undergraduate programs at predominantly white institutions suggests that several aspects of these programs still could be contributing to the departure of minority students. The first is the set of vocabulary/concepts used by the national agencies creating these programs, which assumes a universality of meaning among them and among the faculty who run such programs. This is not a justified assumption, because key areas such as mentoring are far from similar in practice. The second concerns the impact of various parts of the larger social environment. Today neither college-going nor science is uniformly highly regarded by segments of the population. At the same time, people of color are still far from equal in society or the economy, or equally represented in science. From society at large, students in these programs also are part of the microsocial system of the laboratory in which the undergraduate performs research. The complexities of social relationships within each laboratory play a role in confirming or negating a student's interest in pursuing research. Yet another aspect of the broader environment is the kind of institution and departments in which these programs operate. Institutions seriously dedicated to teaching, with a demonstrated commitment to diversity by employing a diverse faculty, appear more likely to achieve greater success with these programs because they provide role models of color and an environment centered on student learning; however, this conclusion is not definite because there has been too little research on it.[3] Finally, we looked at 2 different types of successful programs: one drawing on an already highly selected population within UC Berkeley, the other a high school–to-college program that works with underachieving, possibly problematic, students to induct them into a world of academic success and the mores of the professional world. Students are in these programs for several years and are provided with extensive training, counseling, coaching, and overall support. Both are demonstrably very successful. But their success rests on addressing the needs and issues of the whole student affected by ethnic/cultural issues, poverty, and academic underachievement. They make the point that to truly broaden participation in the biomedical pipeline, programs must address more than science. They must offer a very broad range of support activities for the whole student, requiring a large number of personnel and likely a high dollar cost.

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