J Sci Educ Technol (2009) 18:535–545
DOI 10.1007/s10956-009-9168-0

Increasing Diversity in Science and Health Professions: A 21-Year Longitudinal Study Documenting College and Career Success

Marilyn A. Winkleby · Judith Ned · David Ahn · Alana Koehler · Jeanne D. Kennedy

Received: 3 March 2009 / Accepted: 27 April 2009 / Published online: 22 May 2009

Abstract Despite decades of precollege science education programs, African Americans, Latinos, and Native Americans remain critically underrepresented in science and health professions. This report describes college and career outcomes among graduates of the Stanford Medical Youth Science Program (SMYSP), a 5-week summer residential program for low-income high school students among whom 97% have been followed for up to 21 years. Approximately 24 students are selected annually, with participation limited to low-income students who have faced substantial personal hardships. Undergraduate and medical students provide key program leadership and training. The curriculum is based on science inquiry education and includes hospital internships, anatomy practicums, research projects, faculty lectures, college admissions/standardized test preparation, and long-term college and career guidance. A total of 476 high school students participated between 1988 and 2008, with 61% from underrepresented ethnic minority groups. Overall, 78% of African American, 81% of Latino, and 82% of Native American participants have earned a 4-year college degree (among those admitted to college, and excluding those currently attending college). In contrast, among 25–34-year old California adults, 16% of African Americans, 8% of Latinos, and 10% of Native Americans earn a 4-year college degree. Among SMYSP's 4-year college graduates, 47% are attending or have completed medical or graduate school, and 43% are working as or training to become health professionals. SMYSP offers a model that expands inquiry-based science education beyond the classroom, and recognizes the role of universities as "high school interventionists" to help diversify health professions.

Keywords Science outreach · Informal science education · Summer science program · Program evaluation · Longitudinal impact

M. A. Winkleby (✉) · J. Ned · D. Ahn · A. Koehler
Stanford Prevention Research Center, Stanford University School of Medicine, Medical School Office Building, 251 Campus Drive, Stanford, Palo Alto, CA 94305-5411, USA
e-mail: winkleby@stanford.edu

J. D. Kennedy
Health Services and Nonprofits Consulting, Stanford Medical Youth Science Program Advisory Board Chair, Palo Alto, CA, USA

Introduction

The demographic and technological changes in the U.S. population have created an urgent need for a diverse workforce in science and health professions (Committee on Prospering in the Global Economy of the 21st Century, National Academy of Science 2007; National Science Foundation Division of Science Resources Statistics 2007; Reede 2003); one that includes African-Americans, Latinos, and Native Americans who remain highly underrepresented among those who earn college and more advanced degrees (Association of American Medical Colleges, Division of Diversity Policy and Programs 2005; U.S. Department of Education, National Center for Education Statistics 2007b). Despite decades of federally- and non-federally-sponsored programs, few educational initiatives have met this need, resulting in large disparities in science education and workforce diversity (Atwater 2000; Education Trust-West 2006; Grumbach and Mendoza 2008).

The disparities begin early, especially for underrepresented minority students. By 8th–11th grades, 70% of African American and 64% of Latino students in California

score below basic proficiency in algebra and geometry compared with ~30% of White, non-Hispanic and Asian American students (Atwater 2000; Education Trust-West 2006). These math courses are not only key "gateway" courses to college and the professional workforce, they are more predictive of success in college than family income or ethnicity (Education Trust-West 2006). Furthermore, by 11th grade, more than 50% of African American and Latino students in California score below the basic level on English proficiency tests. These statistics do not include the large number of students who begin high school but drop out before graduation; 22% of Latino, 14% of Native American, and 10% of African American students drop out compared with 6% of White, non-Hispanic and 3% of Asian students (U.S. Department of Education, National Center for Education Statistics 2007b).

The 4-year college graduation rates for students from these three underrepresented minority groups, who represent 25% of the U.S. population, are 15% for African Americans and 10% for Latinos and Native Americans, compared with 31% for White, non-Hispanics and 55% for Asians (Babco 2005; U.S. Census Bureau 2003). When low-income status is factored in, the statistics are even more sobering. In California, only 3% of students who attend college are from families whose incomes are in the lowest 25th percentile of the income distribution (Carnevale and Rose 2003). Such educational disparities are especially germane to California that became the first non-white majority state in 2000. It is predicted that the rest of the nation will follow this trend, with 50% of the U.S. population expected to be ethnic minority by the year 2050 (U.S. Census Bureau 2004b).

Over the last 30 years, the U.S. has had an extensive history of programs and initiatives developed to enhance the interest and academic success of underrepresented ethnic minority students in higher education and science/health professions, and to increase the numbers of such students in the educational pipeline. Many programs have increased the number of matriculants into medical and other professional schools by reaching out to high-achieving, ethnic minority students who have completed their postsecondary educations (Cantor et al. 1998; Gándara and Maxwell-Jolly 1999; Grumbach and Chen 2006). Far fewer programs have been designed for K-12 students to assist them through the educational pipeline. For example, the Academic Competitiveness Council recently released one of the most thorough reports on educational programs aimed at improving America's competitiveness in science, technology, engineering, and mathematics (STEM). Of the 105 federally-sponsored STEM education programs in 2006, only 18% focused on K-12 education while 77% focused on post-secondary education (and 5% on informal outreach programs) (U.S. Department of Education 2007a).

Unfortunately, few of the federally- or non-federally-funded K-12 programs that have focused on science and health professions have conducted and/or reported evaluation results on the long-term impact of their programs, such as student achievement in the sciences or completion of graduate/medical school (Cota-Robles and Gordan 1999; U.S. Department of Education 2007a). Among programs that have reported evaluation data, many have shown promising results (Bauman 1991; Beck et al. 1978; Brickhouse 1994; Brown 2004; Butler et al. 1991; Cregler 1993; Davis and Davidson 1982; Fadigan and Hammrich 2004; Felix et al. 2004; Jayaratne et al. 2003; Jones and Flowers 1990; Lee 2001; Markowitz 2004; Marshall 1973; McKendall et al. 2000; Nickens et al. 1994; O'Loughlin 1992; Roseberry et al. 1992; Thurmond and Cregler 1994), but most have been compromised by small sample sizes, low response rates, and/or insufficient follow-up time to evaluate college and career outcomes. Few or no programs have reported long-term impact data specific to the ethnicity of student participants. The lack of programs reporting long-term educational outcomes led the Academic Competitiveness Council to conclude that, "despite decades of significant federal investment in science and math education, there is a general dearth of evidence of effective practices and activities in STEM education" (U.S. Department of Education 2007a).

In this paper, we present 21 years of follow-up data from the Stanford Medical Youth Science Program (SMYSP), a 5-week summer residential biomedical program that seeks to enlarge the pool of underrepresented ethnic minority and low-income students who succeed in college, the sciences, and eventually in science and health professions. Each year approximately 24 low-income high school students are selected to participate (from 1988–1995, 19–22 students participated and from 1996–2008, 23–24 students participated). They live on the Stanford University campus with 10 Stanford undergraduate student staff, most of whom are from underrepresented ethnic minority groups and majoring in the sciences, with plans to become health professionals.

This university-based program's curriculum is based on two complementary teaching and learning theories, Cognitive Apprenticeship (Collins et al. 1991) and Situated Learning (Lave and Wenger 1991). These theories posit that when educational activities take place in an authentic context and learning involves participation in a community of practice, then student learning and retention is improved. The curriculum is also consistent with typologies identified in the precollege enrichment program literature—scientific inquiry, apprenticeship, academic enrichment, research experiences, mentorship (Carline and Patterson 2003; Carline et al. 1998), inquiry-based science education (Hmelo-Silver et al. 2007; Minstrell and van Zee 2000), and culturally-diverse learning environments (American

Association for the Advancement of Science 1998; Brickhouse 1994; Brown 2004; Carter 2008; Lee 2001; Lynch 2000; O'Loughlin 1992; Roseberry et al. 1992), as described below:

- Scientific inquiry/hands-on science: Students spend 8 h a week in the anatomy laboratory, dissecting human cadavers and being taught by Stanford medical students. The teaching follows a systems approach, complemented by discussions of family and personal risk factors, and completion of web-based activities.
- Apprenticeship/hospital internships: Students spend 2 days a week in hospital internships where they work side-by-side with physicians and other health professional mentors, in departments including surgery, labor and delivery, physical therapy, and emergency medicine.
- Academic enrichment/faculty lectures/college admissions: Students attend 8–10 lectures a week given by prominent faculty, on topics ranging from the basic sciences to public health to physician advocacy. In addition, students spend 8 h a week in activities to enhance their knowledge of the college admissions process (e.g., test taking strategies, SAT preparation, college applications, college essays, and financial aid).
- Research experiences: Students work in small groups on current health problems including diabetes, obesity, substance use, and mental health disorders. With the guidance of the Stanford student staff, they formulate study questions, critique scientific literature, and prepare scientific posters and oral presentations that they present to over 200 health professionals, families, and community members at graduation.
- Mentorship/role models/long-term guidance: Students are paired with the Stanford student staff, medical students, faculty, other health professionals, and alumni of the program who serve as role models and mentors. Students receive college and career guidance throughout their undergraduate years and beyond (e.g., letters of recommendation, financial aid advice, mock interviews for medical school).

Since its inception in 1988, 476 students have participated in SMYSP and extensive evaluation data are available for 97% of the students. Two earlier reports presented a medical news perspective about the program in its beginning years (Goldsmith 1994) and a description of the curriculum and initial outcomes (Winkleby 2007). In this report we address the following study questions in relationship to the participants' ethnicity: (1) What are the personal, academic, and neighborhood characteristics of SMYSP participants? (2) What are the long-term college and career outcomes of participants? (3) How do 4-year college graduation rates of participants compare with those of young adults in California and the U.S.? and (4) What components of the curriculum do participants feel are most useful for their academic success?

Methods

Selection for SMYSP is based on the following criteria: being from a low-income family, having completed the sophomore or junior year in high school, and having an interest in the science and health professions. Priority is given to students who are the first in their families to attend college, have faced substantial personal hardships (e.g., death or imprisonment of a parent, family alcohol or drug addiction, foster care placement), and are from under-resourced schools and/or communities (e.g., rural and inner-city schools, agricultural labor camps). While all students must have taken biology and earned a B or above in one science or math class, the program does not specifically target high-achieving students. Rather, the program places an emphasis on students who lack knowledge of the college admissions process and have poor academic preparation and/or low standardized test scores.

Recruitment begins each December when application packets are sent to ~300 Northern California high schools and community-based organizations. The application consists of a description of family background, official high school transcript, copies of standardized test scores, two letters of recommendation (from teachers, counselors, or mentors), and four essays about the student's current life experience, interest in science, career goals, and personal hardships. Low-income status is determined by an evaluation of parents' or guardians' educations and occupations, family income, number supported by the family, and cost of living in the family's geographic area. Approximately 250–300 students apply each year.

Each application is reviewed independently by two of the Stanford student staff, scored from 1–5, and re-reviewed if the 2 scores show a discrepancy of more than 2 points. The top 100 applicants are interviewed by telephone and 45 finalists attend Stanford for a day of group discussions and personal interviews. The program's executive director, faculty director, and student staff select the final class of 24, which is balanced by gender and ethnicity to reflect California's diverse population.

The 24 high school students and 10 Stanford student staff live in a residential house on Stanford's campus that becomes a vibrant learning environment. The program is intense but cooperative, with student activities beginning at 9:00 a.m. and ending at 10:30 p.m. including weekend days. Participation is free of charge and includes tuition, room and board, and all educational and other costs. The summer residential program is only the beginning for some students, as program activities (e.g., annual alumni

reunions), workshops (follow-up standardized test preparation), and college and career guidance (e.g., one-on-one advising, letters of recommendation) are offered for years after participation (Winkleby 2007).

The SMYSP web site (http://smysp.stanford.edu) provides detailed information about the summer residential program, the college admissions process, health careers, and profiles of alumni for students, families, teachers, and community members. In 2007, the SMYSP Alumni Association was formed to provide a leadership structure and communication system for alumni and former staff.

The program is funded by grants from foundations, the government, and private donors—all initiated by the SMYSP staff. In-kind support is received from faculty and staff at Stanford University, Stanford Hospital and Clinics, Stanford School of Medicine, and the Veterans Affairs Palo Alto Health Care System. The program is overseen by the faculty director (5% time), executive director and administrator (both full time), and evaluator (25% time). The program is approved by the Stanford Institutional Review Board and conforms to the principles of the Declaration of Helsinki.

Evaluation

Evaluation begins with a baseline and a post-survey that are administered in person to students on the first and last days of the summer program. It continues with an annual survey conducted by telephone or email to assess long-term college and career outcomes. The baseline survey collects contact information about the participant, his/her parents, and two relatives or friends who will know his/her whereabouts. It also collects information on attitudes and beliefs about science and college as well as sociodemographic information about the student and his/her family, student academic preparation, and college and career plans. The post-survey collects data on changes in attitudes and beliefs, and college and career plans. The annual survey is tailored to the educational status of the student (still in high school, undergraduate college, graduate or professional school, working) and updates the student's contact information, and college and career status.

Ethnicity is based on the student's self-reported ethnicity, and is classified according to the following categories, consistent with the U.S. census (U.S. Census Bureau 2003).

African American (African, African American, Black),
Asian (Burmese, Cambodian, Chinese, Filipino, Hmong, Indian, Japanese, Korean, Laotian, Mongolian, Taiwanese, Thai, Vietnamese),
Latino (Hispanic, Mexican, Mexican-American, Central American, South American, Puerto Rican, Cuban),
Native American (American Indian, Native American),
White, non-Hispanic (Caucasian, European), and
Other ethnicity, including mixed ethnicity.

Student's college major is determined from an open-ended question and then categorized as biological sciences (e.g., biology, biochemistry, genetics, microbiology, neurobiology, physiology), physical sciences/engineering (e.g., chemistry, physics, engineering), or other majors (e.g., anthropology, business, English, political science, sociology, foreign language).

All survey data are entered into a comprehensive database. A student/staff directory is generated each year from the database and mailed to alumni.

Analyses

For the present paper, we generated descriptive statistics to describe the sociodemographic and academic characteristics of the participants. To characterize the neighborhood environment where the participants lived and attended school at the time of the program, we geocoded their home and high school addresses which we then linked to U.S. census tract characteristics (e.g., % of residents in the neighborhood with less than a high school education, % unemployed) (Moore and Carpenter 1999). We used the 1990 census data for the first classes (1988–1990) and the 2000 census data for the later classes (2000–2007). For the intermediate classes, we estimated the neighborhood environment with a linear interpolated value from the two censuses. We used general linear models to test whether the participants' rankings of the main components of the curriculum differed by gender, ethnicity, or year of participation.

Results

From 1988 through 2008, 476 students participated in SMYSP. Every student successfully completed all aspects of the 5-week program. All students were from low-income families, with 61% from underrepresented ethnic minority groups (23% African American, 34% Latino, 4% Native American) (Table 1). The large majority of African American, Native American and White, non-Hispanic participants were born in the U.S. (87, 100, and 78%, respectively) compared with 57% of Latino and 28% of Asian participants. The educational attainment of Latino students' parents was particularly low, with 63% of their mothers having less than a high school education. In contrast, 53% of African American students had a mother who completed at least some college. A number of students had one or both parents who were deceased (9%). Many others had parents who were disabled, incarcerated, and/or who

Table 1 Personal, academic, and neighborhood characteristics of 476 Stanford Medical Youth Science Program (SMYSP) participants by ethnic group, 1988–2008

	African American ($n = 110$)	Asian ($n = 126$)	Latino ($n = 161$)	Native American ($n = 20$)	White, non-Hispanic ($n = 32$)	Other ethnicity ($n = 27$)	Total ($n = 476$)
Personal characteristics							
Gender (%)							
Male	44.5	46.8	54.7	45.0	43.8	48.1	48.7
Female	55.5	53.2	45.3	55.0	56.2	51.9	51.3
Country/regions of birth (%)							
United States	87.3	27.8	56.5	100.0	78.1	33.3	58.0
Africa	12.7	0.0	0.0	0.0	0.0	3.7	3.1
Mexico, Central, and South America	0.0	0.8	43.5	0.0	0.0	0.0	14.9
Southeast and East Asia	0.0	70.6	0.0	0.0	0.0	3.7	18.9
Europe	0.0	0.0	0.0	0.0	18.8	3.7	1.5
Other	3.2	0.8	0.0	0.0	3.1	55.6	3.6
Mother's highest year of education (%)							
<9 years	5.8	33.3	40.0	0.0	0.0	19.2	24.9
9–11 years	8.6	20.3	22.5	15.0	18.8	11.5	17.6
12 years	32.7	27.6	26.9	60.0	40.6	46.2	31.8
13–15 years	38.5	10.6	7.5	25.0	25.0	15.4	17.6
≥16 years	14.4	8.1	3.1	0.0	15.6	7.7	8.0
Father's highest year of education (%)							
<9 years	19.6	34.7	46.5	0.0	9.4	13.0	31.2
9–11 years	6.2	12.4	16.5	10.5	21.8	8.7	12.9
12 years	37.1	24.8	23.6	68.4	28.1	30.4	29.4
13–15 years	19.6	10.7	8.3	21.1	15.6	17.4	12.9
≥16 years	17.5	17.4	5.1	0.0	25.0	30.4	13.6
Parent(s) deceased (%)	9.1	7.1	6.8	15.0	12.5	14.8	8.6
Academic preparation[a]							
GPA ($\bar{x}$)	3.4	3.8	3.5	3.2	3.5	3.6	3.6
Math and/or science classes ($\bar{x}$)	3.6	4.3	3.9	3.7	3.5	3.7	3.9
Neighborhood characteristics							
Census tract of home residence							
Less than high school education (%)	27.3	25.7	35.6	21.1	20.9	19.4	28.4
Annual family income ($)	42,252	48,719	46,111	45,354	51,474	57,699	46,984
Unemployed (%)	6.8	6.0	7.0	5.7	4.8	4.7	6.3

Numbers vary slightly because of missing data

[a] At time of participation in SMYSP. Data only available on 221 (46%) of students

had been homeless (data not shown). The academic preparation of students at the time of their participation varied (GPAs ranging from 2.2 to 4.0, students with no honors classes to those with several honors classes, students who had taken standardized tests to those who had not heard of the tests). High school transcripts were optional in the early years and are available for only 46% of the students. Although this subset most likely represents the higher achieving students, their mean GPA was 3.6; 11% had a C average, 31% a B- to a B average, and 58% a B+ or A average. These students had taken an average of 3.9 math and/or science high school classes.

The neighborhood environments where students lived at the time they participated in the program did not differ greatly (Table 1). However, Latino students tended to live in neighborhoods where residents were the least educated,

family income was low, and unemployment was highest; the opposite was true for White, non-Hispanic students and students from other ethnic groups. Characteristics of the neighborhoods where students attended high school followed the same general pattern (data not shown).

Long-term college and career outcomes, available for 97% of the 476 participants, are shown in Fig. 1. Fifty-six students are still completing high school. One hundred percent of age eligible students have graduated from high school and 99% are attending or attended a 2- or 4-year college. Overall, 84% have earned a 4-year college degree (among those admitted to college, but who are not currently attending college), including 78% of African American, 96% of Asian, 81% of Latino, 82% of Native American, and 73% of White, non-Hispanic participants. Among 4-year college graduates, 58% of African American, 47% of Asian, and 42% of Latino participants are attending or have graduated from medical or graduate school. Forty-three percent are working as or are training to become health professionals (i.e., of the 256 college graduates, 109 are employed in health-related jobs, attending/completed medical school, or attending/completed a health profession graduate school. While students with the highest GPAs ($\geq$3.5) were the most likely to graduate from 4-year colleges (93%), even students with lower GPAs (2.2–2.9) succeeded in college (50%), and 50% of these students continued on to medical or graduate school.

Students from every ethnic group were most likely to graduate from a University of California (U.C.) school, especially Asian students, among whom 71% graduated from a U.C. (Table 2). Of students who attended a U.C, 90% graduated from one of the four top ranked schools (U.C. Berkeley, UCLA, U.C. San Diego, or U.C. Davis) (U.S. News and World Report 2008). Students were next most likely to graduate from private universities or the California State University system.

The majority of students majored in the sciences; 51% in the biological sciences and 6% in the physical sciences or engineering. On average, Asian students were about twice as likely to major in the sciences than African American, Latino, Native American, or White, non-Hispanic students (79% vs. 22–46%).

The 4-year college graduation rates for SMYSP participants are compared to graduation rates for young adults in California and the U.S. in Table 3 (U.S. Census Bureau 2005). In this calculation, SMYSP participants who were lost to follow-up or deceased were conservatively classified as not completing a 4-year college degree. College graduation rates were 78% for African American, 96% for Asian, 81% for Latino, 82% for Native American students, and 73% for White, non-Hispanic students. In contrast, graduation rates for 25–34-year-old young adults in California were 16% for African Americans, 51% for Asians, 8% for Latinos, 10% for Native Americans, and 31% for White, non-Hispanics (Babco 2005; U.S. Census Bureau 2004a). Graduation rates for 25–34-year-old young adults in the U.S. were similar to California rates.

In 2008, students from all classes (1988–2008) were asked to rank the main components of the curriculum that they felt were most useful for their academic success, which provides insight about links between program elements and successful outcomes. Students from all classes ranked the anatomy labs and hospital internships first and second, followed by college admissions workshops, mentoring activities, and faculty lectures. The rankings for the anatomy labs and hospital internships were 50% higher than for the other components, and there were no significant differences by gender, ethnicity, or year of participation in a general linear model analysis.

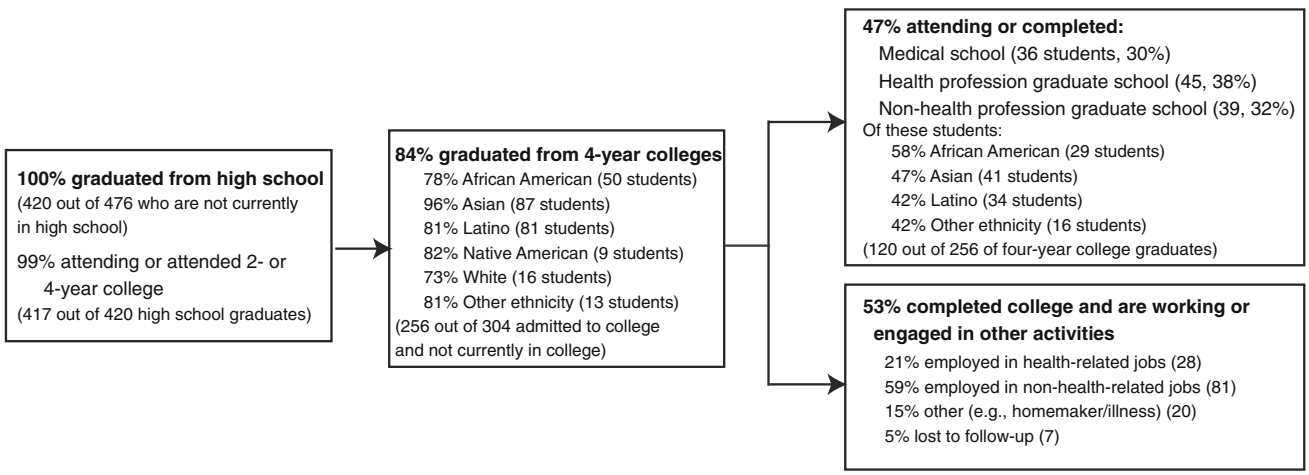

Fig. 1 College and career outcomes, 476 SMYSP participants, 1988–2008

Table 2 Type of college and majors of 256 SMYSP participants who graduated from 4-year colleges, 1988–2008

	African American ($n = 50$) (%)	Asian ($n = 87$) (%)	Latino ($n = 81$) (%)	Native American ($n = 9$) (%)	White, non-Hispanic ($n = 16$) (%)	Other ethnicity ($n = 13$) (%)	Total ($n = 256$) (%)
Type of college							
Universities of California	42.0	71.3	44.4	44.4	37.5	53.8	53.1
California State Universities	12.0	4.6	11.1	0.0	12.5	23.1	9.4
Stanford University	6.0	8.0	12.4	11.1	18.8	7.7	9.8
Ivy League colleges	0.0	1.2	7.4	11.1	6.2	0.0	3.5
Historically Black colleges and universities	12.0	0.0	0.0	0.0	0.0	0.0	2.3
Other private/state colleges or universities	28.0	14.9	24.7	33.3	25.0	15.4	21.9
Major							
Biological sciences	40.0	72.4	39.5	22.2	37.5	61.5	51.2
Physical sciences/engineering	6.0	6.9	4.9	0.0	6.2	15.4	6.2
Other majors	54.0	20.7	55.6	77.8	56.2	23.1	42.6

Table 3 Comparison of 4-year college graduation rates of SMYSP participants to US and California adults, ages 25–34, 1988–2008

	African American (%)	Asian (%)	Latino (%)	Native American (%)	White, non-Hispanic (%)	Other ethnicity (%)	Total (%)
College graduation rates							
SMYSP participants	78	96	81	82	73	81	84
California residents, ages 25–34[a]	16	51	8	10	31	21	26
US residents, ages 25–34[a]	15	55	10	10	31	21	28

[a] From 2000 U.S. census data

Discussion

SMYSP is an example of a university-based science education model that links low-income students who are often from under-resourced schools to science-rich universities. This model is a complement to the more common school-based models, and allows leveraging of university faculty, staff, student, teaching, technology, and laboratory resources. The role of universities as "high school interventionists" is often not recognized but offers many advantages for stimulating, hands-on science programs, apart from standard science textbook learning that increasingly consists of "teaching to the test" (Yager and Falk 2008). By expanding science activities beyond the classroom, activities can be tailored to students' experiences, "where the nature of knowledge can be explored and a lifetime commitment to self-directed learning can be forged" (Friedman and Quinn 2006).

The results of SMYSP support the two teaching and learning theories upon which the program is based—Cognitive Apprenticeship (Collins et al. 1991) and Situated Learning (Lave and Wenger 1991). In utilizing the approach of Cognitive Apprenticeship, SMYSP students directly observe and participate as apprentices during hands-on activities in their hospital and laboratory work and in college admissions workshops. During these activities they observe experts at work, practice the skills they observe, and receive constructive feedback. From this, students enhance their understanding of the skills they put into action and are able to reflect upon their experiences for future reference. Throughout all activities, SMYSP program staff and faculty support the students and foster this model of learning. Additionally, students are exposed to role models with varying levels of skill, which allows them to understand that learning is continuous and part of an incremental process.

SMYSP thus involves a model of instruction where "thinking is visible." One participant observed the value of hands-on science after she completed the anatomy practicums by saying: "I get things visually and by touching things. Our instructor was giving us a lecture about the heart and he was trying to draw it, and I was seeing it in 2-D and thinking 'I'm not going to get this.' Finally, we get inside the anatomy lab, and I can see the atrium, the

ventricle, and actually see the microvalves. When our instructor said, 'When something goes wrong here, you can have a myocardial infarction.' I'm like, I can get this because I can see it." SMYSP also creates learning environments that support the theory of Situated Learning whereby students collectively observe, problem solve, and practice their skills in academic and social environments that foster cooperative learning and a sense of ownership.

Our results suggest that SMYSP positively influences the college success and career decisions of students from all ethnic groups, even in the absence of an internal control group. Overall 84% of SMYSP participants have graduated from 4-year colleges and 47% have continued on to medical or graduate school. These college graduation rates are substantially higher than those for California and U.S. young adults from the same ethnic groups, with the largest differences evident for students from underrepresented minority groups.

The success of Latino participants, who comprise 34% of SMYSP alumni, is especially noteworthy given that Latinos have the lowest levels of educational attainment of any ethnic group in California and the U.S. Only 53% of Latinos in California (and 60% in the U.S.) complete high school by age 29 (U.S. Census Bureau 2005). These students represent a significant group of students who make up 48% of California's 6.3 million public school students in kindergarten through 12th grade. SMYSP Latino students were equally successful in college regardless of their country of birth; 82% of U.S.-born and 78% of foreign-born SMYSP Latino students earned a 4-year college degree; this compares to 12% of U.S.-born and 5% of foreign-born Latinos in California, ages 25 and older (U.S. Census Bureau 2005).

One of the largest ethnic differences among SMYSP alumni was the major they chose in college. On average, Asian students were almost twice as likely to major in the sciences than African American, Latino, Native American, or White, non-Hispanic students. While an interest in the sciences is a requirement for participation in SMYSP, data for the U.S. show a similar two-fold difference; 21% of college-bound Asian American students report an intention to major in science, math, or engineering compared with 13–15% of Native American, Mexican-American and African American students and 17% of white students (Schuman et al. 1998; Summers and Hrabowski 2006). Given these ethnic differences, it is important for future studies to examine influences such as family and faculty support, and high school and college resources on college students' decisions to pursue science majors.

Limitations

The first and major limitation of this study is that it is not a controlled evaluation of SMYSP, but rather a case report with longitudinal data. Although the college graduation rates are high for SMYSP students from all ethnic groups and may be a result of their participation in the program and/or its long-term college and career support, there is also the possibility of selection bias. Students' interest in science and personal motivation are criteria for selection into the program. Without a control group of similar low-income and ethnic minority students, it is impossible to know the degree to which the outcomes represent a program effect and how much they represent a selection effect. However, none of the SMYSP participants are from middle- or high-income families, a factor that has historically been the strongest determinant of whether a high school senior will be qualified for college (Cooper 2003). For example, only 10% of college students who attend the top 146 colleges in the United States are from families with incomes in the bottom half of the nation's income distribution, and only 3% are from families in the bottom fourth (Carnevale and Rose 2003); the latter income bracket represents most SMYSP families.

A second limitation is the lack of data on changes in types of classes and academic performance immediately following the program, such as changes in high school GPAs, enrollment in science and math classes, and completion of honors classes. This limits our ability to evaluate proximate academic outcomes.

Implications for a Diversified Workforce

At the very time when achieving a diverse science and health professional workforce is critical, legislative and policy decisions impede progress. In 1978, a U.S. Supreme Court decision ruled unconstitutional the use of fixed quotas for ethnic minority applicants at professional schools (Davidson and Lewis 1997). In 1996, California voters passed Proposition 209 by a narrow margin that amended the State Constitution to prohibit public institutions from discriminating on the basis of race, ethnicity, or gender. The possible impact of these decisions can be seen in enrollment trends of ethnic minority students in the sciences and health professional schools. The percentage of underrepresented minority students who matriculated into medical schools, which increased significantly following the 1964 Civil Rights Act, leveled out between 1975 and 1990, peaked in 1996, and has steadily fallen since, remaining at about 11% of medical school admissions (Holzer and Neumark 2000). This decrease has resulted in fewer ethnic minority health professionals who are more likely than their counterparts to work in economically disadvantaged communities where medically underserved populations are concentrated, population growth is greatest, and shortages of health care personnel are most acute (Association of American Medical Colleges Division of

Diversity Policy and Programs 2005; Komaromy et al. 1996).

Future Directions

The results of this university-based biomedical pipeline program are highly relevant to health policymakers and government health leaders as well as researchers and academics in medicine and public health. As an example of an evaluated model that seeks continuity, replication, and dissemination, it fits recent calls for strategies for improving the diversity of the health professions (Grumbach et al. 2003; Grumbach and Mendoza 2008). It has been replicated at the University of California, San Diego, School of Medicine, and has expanded its summer residential program to include an understanding of neighborhood influences on health disparities (Adler et al. 1993; Williams and Jackson 2005; Winkleby and Cubbin 2003; Yen and Syme 1999) through a curriculum for teachers in under-resourced high schools. It is one of a number of new programs supported by government agencies and national foundations that seek innovative ways for colleges and universities to enhance K-12 science education. For example, SMYSP was one of six projects funded by the NHLBI Minority K-12 Initiative for Teachers and Students (MKITS Science Program), a $2.4 million program initiated to increase underrepresented minorities in science, research, medicine, and related fields, and address the critical need for a diverse workforce in the science and health professions (http://grants.nih.gov/grants/guide/rfa-files/RFA-HL-02-026.html). SMYSP is currently part of the Howard Hughes Medical Institute's Grants for Precollege Science Education, a $60 million program that seeks to "attract and retain students who will be the future of science" (http://www.hhmi.org/grants/office/precollege/).

The college and career outcomes of SMYSP participants suggest that university-based biomedical pipeline programs can help low-income and underrepresented ethnic minority students distinguish themselves academically and succeed in the science and health professions. Among the next steps needed is support for programs that are designed as randomized controlled trials or use well-matched comparison groups (U.S. Department of Education 2007a). For example, it would be feasible for SMYSP to conduct a case/control study where every new SMYSP participant is matched to 2–3 controls (such as on sex, ethnicity, rural/urban school, and grade point average) from students who apply to the program but are not selected. Such a study would allow the testing of whether SMYSP has an independent effect on college and career outcomes above and beyond the effects of personal and academic factors such as motivation, family support, or academic preparation. Evaluation data are also needed to assess why pipeline programs work, curriculum components that contribute most to successful outcomes, differences between university- and school-based programs, and types of students who benefit most. With this understanding comes the need for colleges and universities as well as governmental agencies to fully integrate diversity and educational efforts into their core missions and institutional functioning (Association of American Colleges and Universities 2008). From this, broad coordinated commitments can be made that help sustain, disseminate, and expand successful programs to address the pressing need to diversify science and health professions.

Acknowledgments The following grants to Dr. Winkleby funded this work: The Stanford MKITS Science Program: CVD and Public Health (National Heart, Lung, and Blood Institute, R25 HL075748); Howard Hughes Medical Institute's Grants for Precollege Science Education (Grant # 51006099); Stanford Medical Youth Science Program School-Based Science Initiative (Fund for the Improvement of Postsecondary Education, FIPSE, U.S. Department of Education, P116B040327); and Stanford College Outreach Program in Education (California Educational Facilities Authority, CEFA 94215). In-kind resources are provided by: Stanford University, Stanford School of Medicine, Stanford Prevention Research Center, Stanford Hospital and Clinics, Lucile Packard Children's Hospital, and the Veterans Affairs Palo Alto Health Care System. The authors thank Nell Curran and Dale Lemmerick for leadership within the organization, Kathleen Fagliano for the annual evaluation of students, members of the SMYSP advisory board, and the many foundations and individual donors that have helped sustain the program over the years. The authors also thank Julia Steele, Kathy Sloane, and Abby Ginzberg who contributed to the SMYSP book, *Healing Journeys: Teaching Medicine, Nurturing Hope,* and the SMYSP documentary film, *Opportunity of a Lifetime*.

References

Adler NE, Boyce T, Chesney M, Folkman S, Syme L (1993) Socioeconomic inequalities in health: no easy solution. JAMA 269:3140–3145. doi:10.1001/jama.269.24.3140

American Association for the Advancement of Science (1998) Chapter 1: equity, blueprints for reform. Science, mathematics, and technology education. Oxford University Press, New York, pp 1–16

Association of American Colleges and Universities (2008) Making excellence inclusive: diversity, inclusion, and institutional renewal, [webpage]. Retrieved January 22, 2008, from http://www.aacu.org/inclusive_excellence/index.cfm

Association of American Medical Colleges Division of Diversity Policy and Programs. (2005) Minority Students in Medical Education: Facts and Figures 2005. Washington, D.C.: Association of American Medical Colleges. Retrieved www.aamc.org/factsandfigures

Atwater MM (2000) Equity for Black Americans in precollege science. Sci Educ 84(2):154–179. doi:10.1002/(SICI)1098-237X(200003)84:2<154::AID-SCE2>3.0.CO;2-R

Babco EL (2005) The status of Native Americans in science and engineering, [PDF]. Commission on Professionals in Science and Technology. Retrieved 12/1/06, from http://www.cpst.org/NativeIV.pdf

Bauman R (1991) Minority students and the health professions: the organizational changes required to attract and retain them. Equity Excell Educ 25(2):22–30. doi:10.1080/1066568910250203

Beck P, Githens JH, Clinkscales D, Yamamoto D, Riley CM, Ward HP (1978) Recruitment and retention program for minority and disadvantaged students. J Med Educ 53(8):651–657

Brickhouse N (1994) Bringing in the outsiders: reshaping the sciences of the future. J Curric Stud 26(4):401–416. doi:10.1080/00220270940260404

Brown BA (2004) Discursive identity: assimilation into the culture of science and its implications for minority students. J Res Sci Teach 41(8):810–834. doi:10.1002/tea.20228

Butler WT, Thomson WA, Morrissey CT, Miller LM, Smith QW (1991) Baylor's program to attract minority students and others to science and medicine. Acad Med 66(6):305–311. doi:10.1097/00001888-199106000-00001

Cantor JC, Bergeisen L, Baker LC (1998) Effect of an intensive educational program for minority college students and recent graduates on the probability of acceptance to medical school. JAMA 280(9):772–776. doi:10.1001/jama.280.9.772

Carline JD, Patterson DG (2003) Characteristics of health professions schools, public school systems, and community-based organizations in successful partnerships to increase the numbers of underrepresented minority students entering health professions education. Acad Med 78(5):467–482. doi:10.1097/00001888-200305000-00008

Carline JD, Patterson DG, Davis LA, Irby DM (1998) Precollege enrichment programs intended to increase the representation of minorities in medicine. Acad Med 73(3):288–298

Carnevale AP, Rose SJ (2003) Socioeconomic status, race/ethnicity, and selective college admissions (PDF). New York, NY: The Century Foundation. Retrieved March 5, 2008, from http://www.tcf.org/list.asp?type=PB&pubid=252

Carter L (2008) Sociocultural influences on science education: innovation for contemporary times. Sci Educ 92(1):165–181. doi:10.1002/sce.20228

Collins A, Brown JS, Holum A (1991) Cognitive apprenticeship: making thinking visible. Am Educ 15(3):6–11 38–46

Committee on Prospering in the Global Economy of the 21st Century, National Academy of Science (2007) Rising above the gathering storm: energizing and employing America for a brighter economic future. National Academies Press, Washington

Cooper RA (2003) Impact of trends in primary, secondary, and postsecondary education on applications to medical school. II: considerations of race, ethnicity, and income. Acad Med 78(9):864–876. doi:10.1097/00001888-200309000-00004

Cota-Robles EH, Gordan EW (1999) Reaching the top: a report of the National task force on minority high achievement. New York: The College Board. Retrieved March 5, 2008, from http://www.collegeboard.com/research/pdf/reachingthe_3952.pdf

Cregler LL (1993) Enrichment programs to create a pipeline to biomedical science careers. J Assoc Acad Minor Phys 4(4):127–131

Davidson RC, Lewis EL (1997) Affirmative action and other special consideration admissions at the University of California, Davis, School of Medicine. JAMA 278(14):1153–1158. doi:10.1001/jama.278.14.1153

Davis JA, Davidson CP (1982) The Med-COR study: preparing high school students for health careers. J Med Educ 57(7):527–534

Education Trust-West (2006) Achievement in California 2006: Small Gains, Growing Gaps (Report). Oakland, CA. Retrieved http://www2.edtrust.org/NR/rdonlyres/CEB9467F-BD78-4CD5-8C4F-E4F54DA51CDE/0/ETWAchievementinCA2006.pdf

Fadigan KA, Hammrich PL (2004) A longitudinal study of the educational and career trajectories of female participants of an urban informal science education program. J Res Sci Teach 41(8):835–860. doi:10.1002/tea.20026

Felix DA, Hertle MD, Conley JG, Washington LB, Bruns PJ (2004) Assessing precollege science education outreach initiatives: a funder's perspective. Cell Biol Educ 3(3):189–195. doi:10.1187/cbe.03-10-0017

Friedman LN, Quinn J (2006) Science by stealth. How after-school programs can nurture young scientists and boost the country's scientific literacy. Education Week 25(24):45 48, 49

Gándara P, Maxwell-Jolly J (1999) Priming the pump: strategies for increasing the achievement of underrepresented minority undergraduates (PDF). The College Board. Retrieved March 5, 2008, from http://professionals.collegeboard.com/data-reports-research/cb/priming-the-pump

Goldsmith MF (1994) 'Med prep' college course helps high school students work toward dreams. JAMA 271(19):1467–1468. doi:10.1001/jama.271.19.1467

Grumbach K, Chen E (2006) Effectiveness of University of California postbaccalaureate premedical programs in increasing medical school matriculation for minority and disadvantaged students. JAMA 296(9):1079–1085. doi:10.1001/jama.296.9.1079

Grumbach K, Mendoza R (2008) Disparities in human resources: addressing the lack of diversity in the health professions. Health Aff (Millwood) 27(2):413–422. doi:10.1377/hlthaff.27.2.413

Grumbach K, Coffman J, Muñoz C, Rosenoff E, Gándara P, Sepulveda E (2003) Strategies for improving the diversity of the health professions (TCE0802-2003). Woodland Hills, CA: The California Endowment. Retrieved http://www.calendow.org/reference/publications/work_force_diversity.stm

Hmelo-Silver CE, Duncan RG, Chinn CA (2007) Scaffolding, achievement in problem-based, inquiring learning: a response to Kirschner, Sweller, Clark (2006). Educ Psychol 42(2):99–107

Holzer H, Neumark D (2000) Assessing affirmative action. J Econ Lit 38(3):483–568

Jayaratne TE, Thomas NG, Trautmann M (2003) Intervention program to keep girls in the science pipeline: Outcome differences by ethnic status. J Res Sci Teach 40(4):393–414. doi:10.1002/tea.10082

Jones F, Flowers JC (1990) New York's statewide approach to increase the number of minority applicants to medical school. Acad Med 65(11):671–674. doi:10.1097/00001888-199011000-00002

Komaromy M, Grumbach K, Drake M, Vranizan K, Lurie N, Keane D et al (1996) The role of black and Hispanic physicians in providing health care for underserved populations. N Engl J Med 334(20):1305–1310. doi:10.1056/NEJM199605163342006

Lave J, Wenger E (1991) Situated learning: legimate peripheral participation. Cambridge University Press, New York

Lee O (2001) Culture and language in science education: what do we know and what do we need to know? J Res Sci Teach 38(5):499–501. doi:10.1002/tea.1015

Lynch SJ (2000) Equity and science education reform. Lawrence Erlbaum Associates, Mahwah

Markowitz DG (2004) Evaluation of the long-term impact of a university high school summer science program on students' interest and perceived abilities in science. J Sci Educ Technol 13(3):395–407. doi:10.1023/B:JOST.0000045467.67907.7b

Marshall CL (1973) Minority students for medicine and the hazards of high school. J Med Educ 48(2):134–140

McKendall SB, Simoyi P, Chester AL, Rye JA (2000) The health sciences and technology academy: utilizing pre-college enrichment programming to minimize post-secondary education barriers for underserved youth. Acad Med 75(10(Supplement)):S121–S123

Minstrell J, van Zee EH (eds) (2000) Inquiring into inquiry learning and teaching in science. American Association for the Advancement of Science, Washington

Moore DA, Carpenter TE (1999) Spatial analytical methods and geographic information systems: use in health research and epidemiology. Epidemiol Rev 21(2):143–161

National Science Foundation Division of Science Resources Statistics (2007) Women, Minorities, and Persons with Disabilities in Science and Engineering. Retrieved 3/5/08, from http://www.nsf.gov/statistics/wmpd/

Nickens HW, Ready TP, Petersdorf RG (1994) Project 3000 by 2000. Racial and ethnic diversity in US medical schools. N Engl J Med 331(7):472–476. doi:10.1056/NEJM199408183310712

O'Loughlin M (1992) Rethinking science education: beyond piagetian constructivism toward a sociocultural model of teaching and learning. J Res Sci Teach 29(8):791–820

Reede JY (2003) A recurring theme: the need for minority physicians. Health Aff (Millwood) 22(4):91–93. doi:10.1377/hlthaff.22.4.91

Roseberry A, Warren B, Conant F, Hudicourt-Barnes J (1992) Cheche Konnen: scientific sense-making in bilingual education. Hands On 15:1–19

Schuman H, Steeh C, Bobo LD, Krysan M (1998) Racial attitudes in America. Trends and interpretations, revised edition. Harvard University Press, Cambridge

Summers MF, Hrabowski FA 3rd (2006) Diversity. Preparing minority scientists and engineers. Science 311(5769):1870–1871. doi:10.1126/science.1125257

Thurmond VB, Cregler LL (1994) Career choices of minority high school student research apprentices at a health science center. Acad Med 69(6):507. doi:10.1097/00001888-199406000-00020

U.S. Census Bureau (2003) Census 2000 Summary File 4—United States. Retrieved 1/4/08, from http://www.census.gov/prod/cen2000/doc/sf4.pdf

U.S. Census Bureau (2004a) Educational attainment in the United States: 2004. Population Division, Education and Social Stratification Branch. Retrieved May 1, 2006, from http://www.census.gov/population/www/socdemo/education/cps2004.html

U.S. Census Bureau (2004b) U.S. interim projections by age, sex, race, and Hispanic origin. Retrieved January 4, 2008, from http://www.census.gov/ipc/www/usinterimproj/

U.S. Census Bureau (2005) Current Population Survey, 2005 Annual Social and Economic Supplement. Population Division, Education and Social Stratification Branch. Retrieved January 7, 2008, from http://www.census.gov/population/www/socdemo/educ-attn.html

U.S. Department of Education (2007a) Report of the Academic Competitiveness Council, [PDF]. Retrieved January 22, 2008, from http://www.ed.gov/about/inits/ed/index.html

U.S. Department of Education, National Center for Education Statistics (2007b) The condition of education 2007. Washington, DC: U.S. Government Printing Office. Retrieved http://nces.ed.gov/programs/coe/

U.S. News and World Report (2008) America's best colleges 2008, [webpage]. Retrieved January 4, 2008, from http://colleges.usnews.rankingsandreviews.com/usnews/edu/college/rankings/brief/t1natudoc_brief.php

Williams DR, Jackson PB (2005) Social sources of racial disparities in health. Health Aff (Millwood) 24(2):325–334. doi:10.1377/hlthaff.24.2.325

Winkleby MA (2007) The Stanford Medical Youth Science Program: 18 years of a biomedical program for low-income high school students. Acad Med 82(2):139–145. doi:10.1097/ACM.0b013e31802d8de6

Winkleby MA, Cubbin C (2003) Influence of individual and neighbourhood socioeconomic status on mortality among black, Mexican–American, and white women and men in the United States. J Epidemiol Community Health 57(6):444–452. doi:10.1136/jech.57.6.444

Yager RE, Falk JH (eds) (2008) Exemplary science in informal education settings. Standards-based success stories. National Science Teachers Association Press, Arlington

Yen IH, Syme SL (1999) The social environment and health: a discussion of the epidemiologic literature. Annu Rev Public Health 20(4):287–308. doi:10.1146/annurev.publhealth.20.1.287