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# Effect of early STEMM pipeline programs on recruiting and retaining a diverse healthcare workforce

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# EFFECT OF EARLY STEMM PIPELINE PROGRAMS ON RECRUITING AND RETAINING A DIVERSE HEALTHCARE WORKFORCE

by

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**EFFECT OF EARLY STEMM PIPELINE PROGRAMS ON RECRUITING AND RETAINING A DIVERSE HEALTHCARE WORKFORCE**

**JILLAMIKA PONGSACHAI**

ABSTRACT

Lack of diversity in the science, technology, engineering, mathematics, and medicine (STEMM) has been a problem for many decades and continues to be a concern. Efforts to recruit and retain underrepresented minorities (URMs) in the workforce include outreach programs that target students at different educational levels. Prior studies examined the effects of these programs, basing the success on the number of students who continued to pursue field-specific higher education. In this study, I investigated the effect of outreach programs by reviewing studies on 15 programs and inclusive high schools that recruit students for STEMM. I also examined program components to determine any commonality among these programs to create a guide for developing more effective programs. Based on the review, outreach programs were able to achieve their goals and sustain students' interests in the fields. The common elements found among the programs include: stimulating learning environment, hands-on activities, mentorship, and incentives. Based on the common features of the programs, I predicted that the Boston Area Health Education Center (BAHEC) program has the design of curriculum that can lead to success, but offering a type of mentorship can further ensure the effectiveness of the program.

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| | |
|---|---|
| ABC | Apprenticeship Bridge to College |
| AIDS | Acquired immunodeficiency syndrome |
| APS | Atlanta Public Schools |
| BAHEC | Boston Area Health Education Center |
| CDC | Centers for Disease Control |
| CLRA | College laboratory research apprenticeship |
| ENGAGES | Engaging New Generations at Georgia Tech through Engineering and Science |
| HIV | Human immunodeficiency virus |
| HSSLRA | High school summer research apprenticeship |
| IC | Integrative complexity |
| ISHSs | Inclusive STEM high schools |
| LI | Low income |
| LLU | Loma Linda University |
| MHSSRAP | Minority High School Student Research Apprentice Program |
| MSM | Morehouse School of Medicine |
| MSMP | Medical Student Mentorship Program |
| NCSES | National Center for Science and Engineering Statistics |
| RISE | Research Initiative for Science Excellence |
| RISE | Research Initiative for Student Enhancement program |
| ROEO | Reach One Each One program |

| | |
|---|---|
| SCCT | Social Cognitive Career Theory |
| SEEP | Student Educational Enrichment Program |
| SFDPH | San Francisco Department of Public Health |
| SHARP | Summer HIV/AIDS Research Program |
| SMART | Storm Management and Research Team program |
| SMYSP | Stanford Medical Youth Science Program |
| STEM | Science, technology, engineering, and mathematics |
| STEMM | Science, technology, engineering, mathematics, and medicine |
| URM | Underrepresented minority |
| UTP | Undergraduate training program |

## INTRODUCTION

The lack of diversity within the science, technology, engineering, mathematics, and medicine (STEMM) fields has been a problem for several decades. Figure 1 below shows the racial percentage of graduate students in the science, engineering and health reported by the National Center for Science and Engineering Statistics (NCSES) from 2008 to 2018.

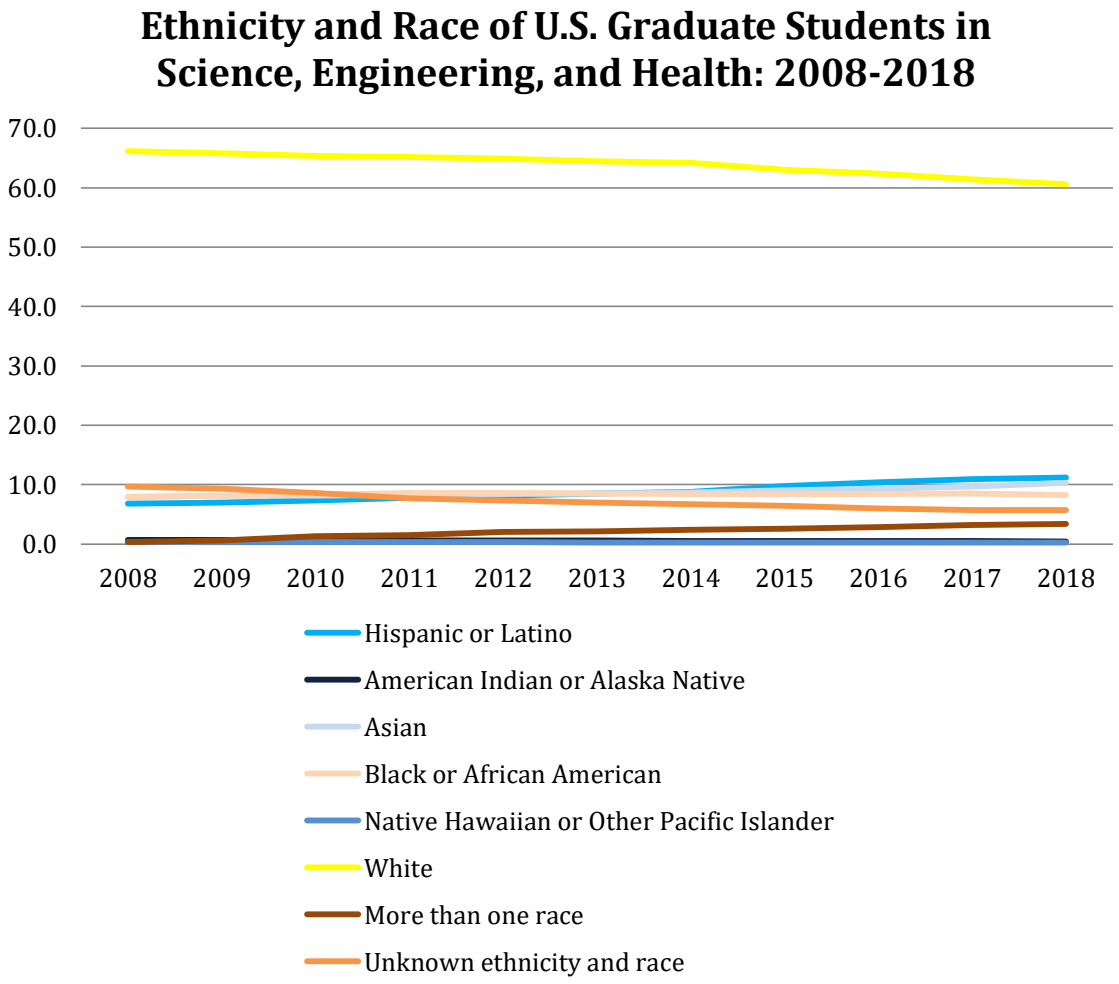

**Figure 1. Ethnicity and Race of U.S. Graduate Students in Science, Engineering, and Health: 2008-2018.** Graphic illustration of data reported by NCSES showing the percentage of U.S. citizen and permanent resident graduate students in science, engineering, and health by race from the year of 2008 to 2018.
**Source of data**: https://www.nsf.gov/statistics/srvygradpostdoc/#tabs-2

Underserved minority groups, such as African Americans and Native Americans, are known to be underrepresented in science, technology, engineering and mathematics (STEM) fields[1]. In 2018, NCSES reported the percentages of graduate students in science, engineering and health as 60.6% White (61.4% in 2017), 11.2% Hispanic (10.9% in 2017), 10.3% Asian (9.7% in 2017), 8.2 African American (8.5% in 2017), 0.4% American Indian (0.5% in 2017), and 0.2 Pacific Islanders (0.2% 2017)[2]. While the number of Hispanic descents who pursued an education in science, engineering, and health increased from 2017 to 2018, the number of African American students decreased from 2017 to 2018. Nevertheless, the data showed that lower numbers of African American and Hispanic graduate students pursued a higher education in science, engineering, and health, compared to the distribution of general U.S. population. Figure 2 illustrates the racial percentages of the general U.S. population in the year 2010 and 2018, reported by the United States Census Bureau[3]. The difference in racial distributions based on Figure 1 and 2 indicates the need to increase diversity in STEMM. The current underrepresentation trends in STEMM will continue to worsen unless more conscious efforts are made to recruit and retain underrepresented minorities (URMs).

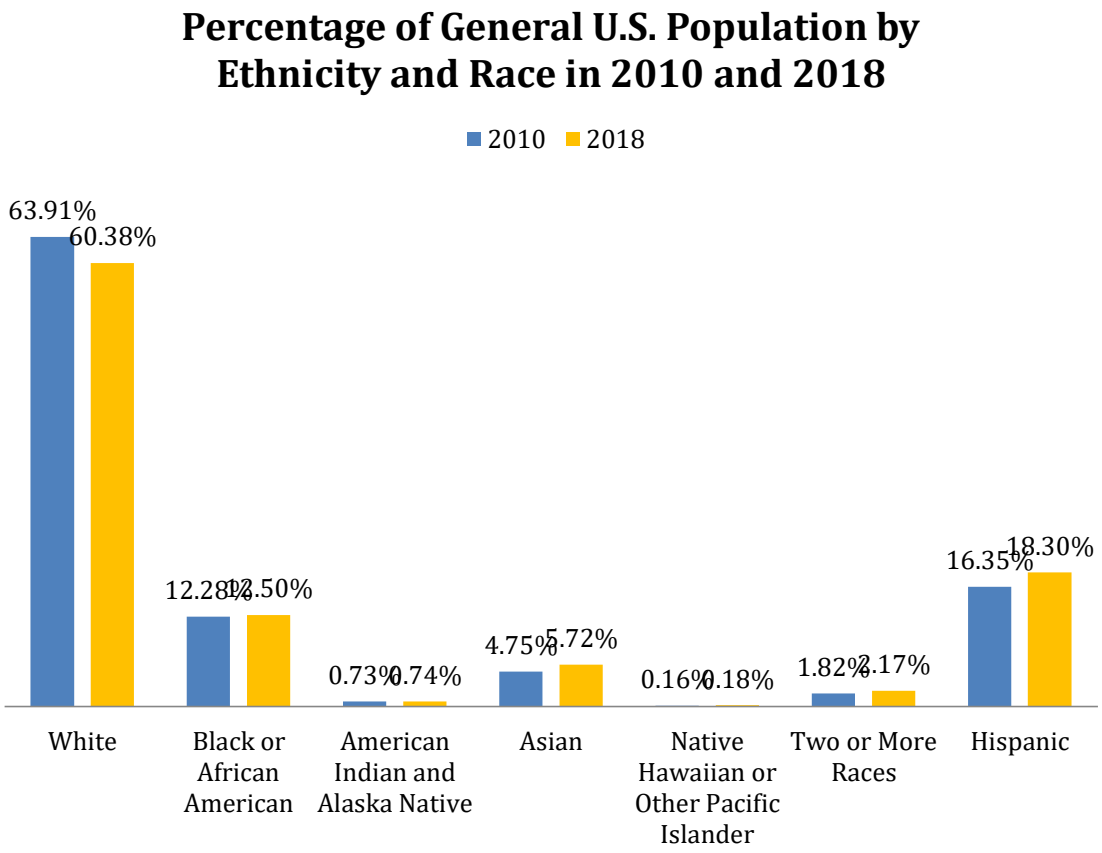


**Figure 2. Ethnicity and Race of General U.S. Population in 2010 and 2018.** Graphic illustration of data reported by United States Census Bureau showing the percentage of U.S. population in 2010 and 2018.
**Source of data**: https://www.census.gov/newsroom/press-kits/2019/detailed-estimates.html

## Roots of Underrepresentation

The causes of underrepresentation in STEMM are complex because dissuasions from fields of interests have many origins and are likely to be different for each person. Some reasons may result from personal experiences and beliefs. Students' confidence in their academic and mathematic abilities can impact their decision on choosing a STEMM

major. Moakler and Minsun (2014) found that students are more prone to choose STEM majors when they have strong confidence in their ability to succeed academically and have parents with STEM occupations[4]. Studies conducted by Steele and other researchers on stereotype threat reported that the academic performance of underrepresented minority can be undermined by students' acknowledgement that people expect them to perform poorly[5–7]. African American and Hispanic students may have experienced stereotype threat in school, leading to poor performances and lower expectations to succeed in future STEM education. Similarly, Wang (2013) reported finding a stronger relationship between early math success and math self-efficacy in those from less-represented groups than that in White and Asian students[8]. Nasir and Shah (2011) explored the role of racialized narratives and reported that male African American students tend to internalize an ethnic hierarchy of achievement in mathematics, such as having Asians on the top and African American and Latino students on the bottom[9]. They reported that students, who were aware of the expectation on their school performance, either embraced the narrative of performing poorly or created a counter-narrative of considering themselves as capable; moreover, they argued that these narratives can influence the way students identify themselves with mathematics and participate in class activities[9]. The difference between student's cultural beliefs and those portrayed in science can also be one of the reasons that instructors interpret students' participation as disinterest[10]. In addition, Native American students often have outlooks on the natural world that are different from that in the science culture[11]. They may feel alienated by STEM instruction because such instruction conflicts with their cultural identity. Other reasons for underrepresentation of

minorities in academic and clinical areas may result from the inadequate number of minority medical school graduates (as shown in Figure 1), lack of mentors, and unawareness of available educational opportunities[12].

**Advantages of Diversity**

If population projections are accurate, the members of underrepresented minorities, such as Hispanic and African Americans, will become the majority population by 2050[13]. In 2005, a committee composed of Nobel Prize recipients and presidents of Ivy League schools wrote the "Rising Above the Gathering Storm" report that questioned the science, engineering, economics, and global competitiveness of the United States. Later in 2010, having reviewed enacted policies and the progress of the nation, the committee continued to express concern about the worsening state of American K-12 education and emphasized the importance of innovation that can arise from a diverse, competent science and engineering workforce for the prosperity of the nation[14].

Diversity in a field is essential because it can lead to many benefits, such as novel innovations and changes in attitudes. A study on the relationship between employee diversity and innovation revealed a positive relation between people being open toward diversity and innovative performance[15]. Other studies found an association between racially diverse educational environments and positive intellectual, social outcomes[16,17]. Experiencing racial diversity had a positive effect on learning for college students, regardless of race[18]. A group of researchers who studied integrative complexity (IC), a degree to which thinking style involves integration of multiple perspectives and

dimension, reported that the presence of a minority opinion led to greater IC[19]. In addition, being in a racially diverse group can positively modify people's behaviors. A study on the effect of racial diversity on group decision making found that diverse groups exchanged a wider range of information than all-White groups and were more lenient toward the Black defendant[20]. People were more likely to be more open-minded and listen to other's opinions when they are surrounded by people from different backgrounds.

The scientific community benefits from a diversity of ideas and perspectives because a diverse group can accelerate innovation, creativity, and new discoveries, and having a diverse group of people can also alleviate some of current issues in healthcare. For instance, increasing the numbers of people from minority groups in the medical field can reduce the shortage of healthcare workers in certain areas because minority physicians are known to be more prone to choose their specialty in primary care medicine and practice in the inner-city and rural regions, where there are medically underserved populations[21,22]. Greater efforts to recruit healthcare practitioners from diverse backgrounds can improve and potentially eliminate healthcare disparities. Furthermore, having healthcare leaders from diverse backgrounds has been argued to be more effective at advocating for and communicating with the populations facing issues such as restricted access to medical care and inconsistent quality[23].

**A Solution to Increase Diversity in Workforce**

Because the numbers of underrepresented ethnic minority groups completing postsecondary education are small, one proposed solution for the lack of diversity is to

promote interests in STEMM from a younger age and train more URMs, such as African Americans, Hispanics, and Native Americans. Such attempts to increase diversity include the development of outreach programs designed to encourage the involvement of minority groups in STEMM. Programs targeted to recruit and prepare minority students for health careers were listed to be factors that maintained the pool of medical student applicants in 2000[24]. Studies found that minorities who chose careers in medicine often decide their career path before they complete high school[12,25]. Many had preference for science while in elementary school[25]. Enrichment programs can help expose students to fields of interests and/or maintain their interests.

Research examining the causes for the smaller numbers of URM in STEM highlighted students' experiences in high school and college, if not earlier. Although interests may have developed at an earlier age, students can change their minds based on the influences of external factors. Seymour (1992) found no significant difference in performance, motivation, or study-related behaviors between undergraduate students who did science majors and those who switched to nonscience[26]. Some of the reported reasons for less preference of the science major were poor teaching, faculty pedagogy, weed-out classes, curriculum design, attraction to more interesting non-science major, poor counseling, and concerns about inadequate high school science preparations[26]. Aschbacher, Li, and Ross (2010) conducted a longitudinal, qualitative study of 33 high school students to examine the factors that made some of the students decide to leave the pipeline while others persisted[27]. They found out that students who persisted had greater participation in science activities, family priorities, and support from school faculty.

Students who lost interest in STEM reported that they were told that science is "hard" and "not for everyone" along with poor, uninspiring teaching that was often provided by substitute teachers[27].

Lacking access to educational opportunities is another reason that dissuades students from STEM. Science and mathematics education for minority students are often deficient at the primary and secondary school levels[12]. Prior research found that students' interests in science began to decline during middle school and continued to decline in high schools, especially for those attending schools with few access to research opportunities and little collaboration with health facilities[21]. Moreover, some schools do not offer upper level STEM classes. Offering advanced STEM courses in school is important because these courses allow students to be more competitive in the college applications and prepare skills for the college level classes[28].

Although URMs were less prone than White and Asian male students to take the courses even if their schools offer advanced STEM courses[29], Cregler (1993) argued that earlier exposure to enrichment programs led to greater results in recruiting URMs into the field[12]. Evidence corroborates that early exposures to STEM, including role models, help students establish their interests and support their later educational pursuits to professional training. Kong and her colleagues (2014) collected data on 1580 students from eight middle schools in five states and found out that those who participated in science summer camps are significantly more prone to report a career in science or engineering than those with no science camp experience[30]. Tai, Liu, Maltese, and Fan

(2006) also suggested that early interests in sciences led to higher likelihood of majoring in sciences and engineering for baccalaureate degrees[31]. Many research studies place importance on high school factors and experiences as main contributors to pursuit of STEM careers[32]. Based on his logistic regression analysis, Tai and his colleagues also indicated that students who reported an interest in science occupation early in 8$^{th}$ grade were three times more likely to earn a college degree in science than those without prior interest[31]. Based on a case study, Aschbacher *et al.* (2010) found that science teachers and experiences stimulated and inspired students to later be interested in careers in science, engineering, or medicine[27].

Enrichment programs or activities developed for high school students are important because these years are the times during which students learn about life and physical sciences, and develop their interest in health-related careers. In addition, programs for high school students can increase the numbers of URMs and low-income students by reaching out to those who are undecided about their future education and career options. Cregler also suggested that an outreach program for careers in the biomedical sciences should be a multiyear, multi-institutional educational continuum through high school, college, and professional school[12]. Literature has reported that research apprenticeship programs are also effective because of their ability to allow students to meet and connect with role models, and to provide students experiences outside of the classroom by working directly with research scientists[33]. Programs that help students throughout the years in their career pursuits can ensure students' motivations and help them maintain interests to stay in the field.

However, underrepresentation of racial minorities can also be attributed to poor degree completion as URMs face challenges moving along the STEM pipeline.[34] The rate at which individuals enter the workforce can be considered as a function of pipeline flow[35]. The pipeline analogy reflects the framework that describes how trainees advance through the educational and training process. Allen-Ramdial and Campbell (2014) suggested seeing the pipeline as a vertical structure that follows the laws of physics, in which forces can oppose the upward force progression into the workforce, resulting in "leaks" or STEM attrition[35]. Outreach programs should be designed and developed to stop and prevent these leaks. Figure 3 below is an adaptation of the diagram by Allen-Ramdial and Campbell that demonstrates the educational pipeline pathway for STEMM and the way outreach programs prevent leaks of students from these fields[35].

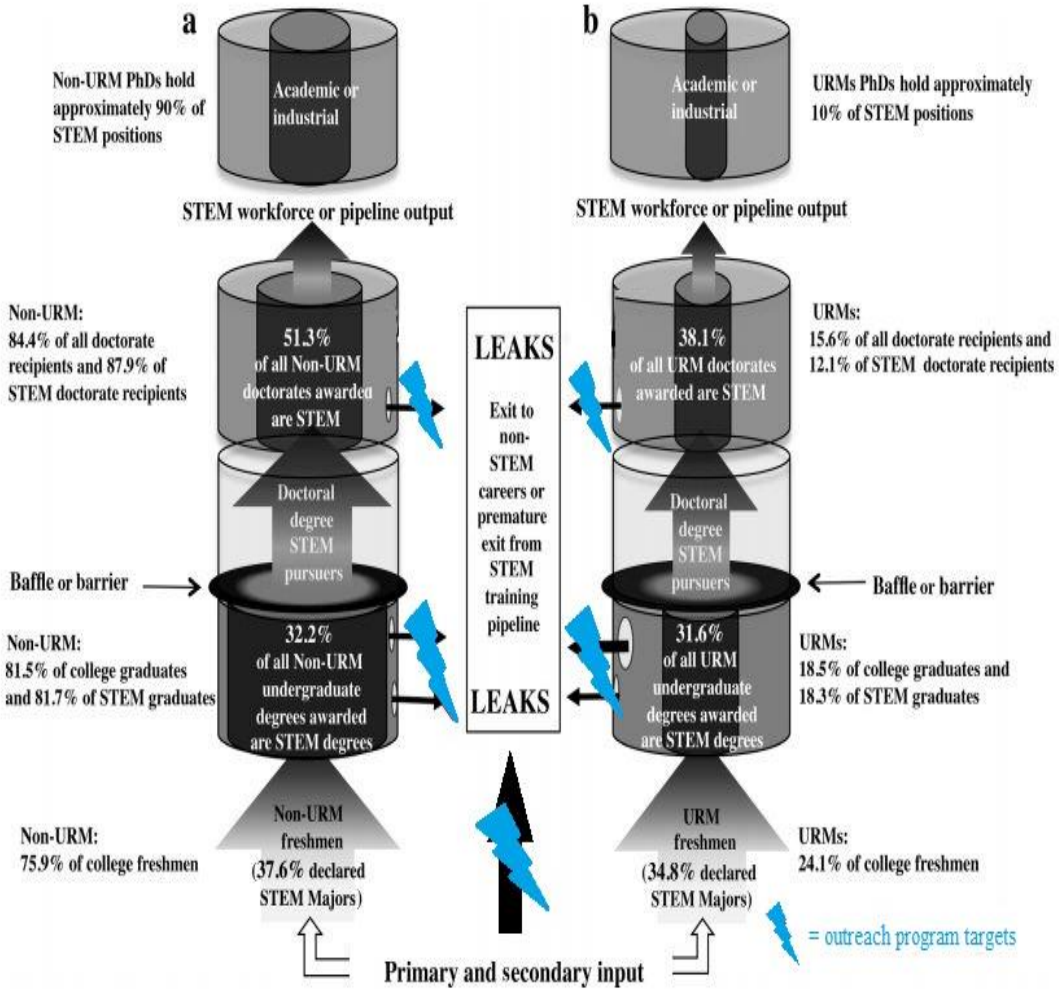


**Figure 3. Pipeline Schematic and Relation with Outreach Programs.** STEM pipeline shows the progression of non-URM and URM trainees from undergraduate to post-doctorate levels. For illustrative purposes, the population is divided into non-URM and URM groups. Shaded upward arrows indicate advancement through STEM training. Small black arrows indicate "leaks" or discontinued interests in STEM training. Blue symbols indicate targets of the outreach programs in attempt to stop the leaks.
**Source:** adapted from Figure 1 by Allen-Ramdial and Campbell (2014)

Although most outreach programs reported success in increasing enthusiasm toward STEMM occupations, not much is known about the efficacy of these programs

and the factors that have contributed to their success. New and existing programs looking for better results have, at best, only intuitive and anecdotal guides that they can follow; the causes of leaks in the pipeline are still speculative. Therefore, it is important to review programs with successful results and examine any common components that can be used as a guideline to create more effective outreach programs. In this research paper, I review reports of different STEM- or STEMM- focused outreach programs and present factors that potentially contribute to the successes of these programs. I also provide explanations for why these factors are helpful, as well as examples of each factor already used in the existing programs. Finally, I evaluate an outreach program supported by Boston University School of Medicine to predict its future results based on its current activities, and to provide suggestions for a better design based on the common factors found.

## PUBLISHED STUDIES

In this section, I provide general descriptions of various outreach programs and their end results. There are 16 programs being examined in this paper. I also reviewed a study on high schools specifically aimed at recruiting students into STEMM. The detailed results of each program are compiled in Table 1-3 at the end of this section.

**List of Programs for High School students:**

1. *Medical Student Mentorship Program (MSMP)*[36]

The objective of MSMP is to ensure the continuance of diverse applicants applying to medical school. MSMP is designed for high school students from lower income family and underrepresented groups. Patel, Rodriguez, and Gonzales (2015) used anonymous surveys from 16 pairs of mentees and mentors to evaluate the success of MSMP. They found out that overall, participants were inclined to apply to medical school after MSMP participation and mentioned receiving helpful support from their mentors, with whom they kept in contact after the program ended. Moreover, several participants reported achievements during their undergraduate studies. One individual received a Gates Millennium Scholar Undergraduate award, while others reported participation in bench research.

2. *Ypsilanti High School Recruitment Through Engagement Program* [37]

Based on a proposal submitted by the University of Michigan School of Dentistry, the Ypsilanti program was created in 2009 to introduce URM and low income (LI) high

schoolers to dentistry and learn from dental and dental hygiene students. The program invited high school students to participate in 15 Saturday sessions each year. The program components include lectures, hands-on activities like setting up a cubicle, and patient-related events (e.g., health fair, shadowing). Inglehart and her team (2014) collected data from the school years 2009-2010, which included 23 high school students, and the year 2010-11, which had 27 high school students. Based on the evaluation, they found that students had increased interest in oral health-related careers and concluded that the program resulted in positive experiences for both the students and their mentors.

*3. Reach One Each One Program (ROEO)*[38]

ROEO is an 11-week multidisciplinary, hospital-based program that offers mentoring and medical exposure to inner-city high school students. Developed within the Morehouse School of Medicine (MSM) Division of Trauma and Surgical Critical Care, ROEO aimed to cultivate future culturally-sensitive and patient-centered care providers to reduce healthcare disparities. Five of its principle objectives include: facilitating students' interaction with hospital personnel from diverse backgrounds to support their pursuit in future careers, exposing students to experiences in medical settings and technology, educating students on the medical school admission process, stimulating interests in surgery and medicine, and helping students determine if a medical-related career as a physician or non-physician personnel is the path for them. Through their retrospective analysis of 26 students, Danner and his colleagues (2017) found that ROEO had a positive impact on the career decisions of URM students.

4. *Project ENGAGES (Engaging New Generations At Georgia Tech through Engineering and Science )*[39]

Partnering with Atlanta Public Schools (APS) system, Project ENGAGES is a year-long research program for African American high school students who are paired with graduate students and postdoctoral researchers at Georgia Tech serving as mentors. The goals of ENGAGES are to provide hands-on research experience, to expose students to STEM careers through field-trips to industrial laboratories, and to provide educational support to improve standardized test scores. Avent and his team (2018) found that ENGAGES students were satisfied with their research experiences, improved their technical skills, and were more interested and curious about STEM careers after participation. They also found that laboratory assignments and interactions with faculty advisors and graduate student mentors were factors that led to positive results.

5. *PULSE* [40]

Led exclusively by medical students, PULSE is a service-learning program that recruits high school students for a semester-long course of lectures and problem-based learning sessions. Its participants also have opportunities to shadow medical providers and form mentorships with the medical students. The goal of PULSE is to cultivate interests in medicine among high school students, especially those from the school districts known to serve large groups of URM students. Karpa and her colleagues (2015) used online questionnaires to determine the effect of PULSE of past participants. They found that more than half of past participants found the program to be a factor in

influencing their decision to pursue careers in medicine or science, and that more than half indicated a desire to pursue a MD/PhD or other post-graduate degree. They concluded that PULSE can help expose students to healthcare opportunities for the first time or to solidify already existing interest.

*6. University of Maine Storm Management and Research Team (SMART) program*[41]

The SMART program started in 2014 with the aim to increase diversity within the water research community. SMART recruits URM and female high school students to build their confidence, better their knowledge, and teach them skills for solving issues within local communities. The program provides resources, such as data collection equipment, and a community mentor network to form long term relationships among mentors and mentees. It supports training for both students and teacher-mentors during the summer, as well as students' research activities during the academic year. Based on the pre-and post- program surveys, students' interests in a STEM career, as well as their understanding of stormwater impact on the community, both increased after program participation. Several SMART students ended up gaining local and national recognition for their stormwater research projects.

*7. Stanford Medical Youth Science Program (SMYSP)*[21,42]

SMYSP aimed to increase diversity in health professions by providing academic enrichment and college admission support, especially for low-income high school students. Since 1988, 24 students have been selected to participate in a 5-week residential program each summer, led by 10 undergraduate students. In 2007, researcher Winkleby

and her team examined the effect of SMYSP through the observations of 405 past SMYSP participants. Her findings showed that most participants earned 4-year college degrees, with more than half majoring in biological and physical sciences. She also showed that half of participants were either attending or have graduated from medical or graduate school. Furthermore, upon a longer period of evaluation in 2015, she continued to find similar positive outcomes from the program, and concluded that the program was able to create a sense of social belonging, self-efficacy, and perseverance toward career goals. The summer residential program appeared to be highly successful in helping low-income students prepare for medical and other careers.

*8. Inclusive STEM High Schools (ISHSs)*[43]

ISHSs are secondary schools or high schools for STEM that admits students based on their interests rather than prior achievement like an examination. These schools aim to prepare academically all of their students with experiences that will help them go into and stay in the STEM pipeline by providing intensive STEM preparation. According to Means and her colleagues, North Carolina and Texas had made substantial investments in establishing ISHSs. Means and her colleagues (2017) used surveys and state records from 39 inclusive STEM high schools and 22 comprehensive high schools in these two states. They excluded schools with intensive programs in which only some students in the school participate, and they regarded non-STEM high schools serving students who were similar in academic achievement prior to school entry as comprehensive or comparison schools. Large proportions of students in ISHSs were from underrepresented groups in

STEM fields. The collected data came from 5,113 students. Means and her team compared URM students from ISHSs to those of the same demographic and similar 8th grade achievement levels from comprehensive schools without a STEM focus. Their data suggested that ISHS students showed stronger interests in STEM and were more likely to pursue a STEM-related career than those in comprehensive schools.

**List of Programs for Undergraduate students:**

1. *Summer HIV/AIDS Research Program (SHARP)*[44]

SHARP is a 12-week program that offers opportunities for HIV-related research, one-on-one mentorship with a HIV investigator, seminars on content and research methods, and networking. It is a program based at the San Francisco Department of Public Health (SFDPH). Fuchs, Kouyate, Kroboth, and McFarland examined four cohorts of SHARP participants from 2012-2015. They found that SHARP participants had better research skills, were more confident in their abilities, and self-identified as scientists. Furthermore, most SHARP alumni were employed in research positions and either had been admitted or were pursuing graduate degrees in fields related to HIV prevention.

2. *Minority High School Student Research Apprentice Program (MHSSRAP)*[25]

MHSSRAP was designed to create interest in the biomedical health sciences among URM youth. Three to six students who were pre-college freshmen and former participants in the Student Educational Enrichment Program (SEEP) were selected each year to be research apprentices. Participants spent 8 weeks with a medical school faculty

member working on biomedical research in a laboratory setting. Based on obtained results, MHSSRAP participants appeared more likely to graduate successfully from college. Thurmond and Cregler (1996) concluded that MHSSRAP is an important link for high school students and science-related careers.

*3. Research Initiative for Science Excellence (RISE)* [45]

RISE is a minority training program funded by the National Institutes of Health. RISE offers mentorships to college students, on-campus research opportunities, graduate school preparation, summer research internships, and annual stipends. Schultz and team (2011) utilized data from the bi-annual surveys over a 3-year period to measure the persistence of students' intent to pursue a research-related career. They recruited matched control samples through a propensity score matching procedure using a large-scale recruitment survey, based on 11 background variables, such as age, gender, and race. Through growth curve analyses of the longitudinal study, they found that RISE participants were more persistent in their pursuit of a scientific research career, and that undergraduate research experience is the factor that led to persistence in pursuit of a science career. They concluded that RISE can sustain students' interest to pursue a research career.

*4. Meyerhoff Scholars program* [46,47]

Meyerhoff Scholars program at the University of Maryland, Baltimore County was funded by Baltimore philanthropists Robert and Jane Meyerhoff. The program focuses on supporting bachelor's degree recipients, especially African Americans, who plan to pursue doctoral programs in science and engineering. The objectives of the program

include academic and social integration, knowledge and skill development, support and motivation, and monitoring and advising. In 2000, Maton and his colleagues began assessing the effectiveness of the Meyerhoff Scholars Program. They looked at survey and interview data, as well as comparison samples, who were students attending the school before Meyerhoff Program began in 1989 and met the admission criteria as the Meyerhoff students. They concluded that the program can help African American undergraduate students to succeed in science, mathematics, and engineering. Looking at the results published by Maton and colleagues, Summers and Hraboswki (2006) concluded that the Meyerhoff program was able to support students, sustain their interests, and contribute to the increasing number of African-American undergraduates majoring in science and engineering.

**List of Programs Targeting Different Educational Levels:**

1. *A Day of Immersive Physiology Experiments*[1]

A group of researchers collaborated with middle and high schools in South Dakota and Nebraska to organize a one-day physiology, activity-based event. The goal of this event is to enhance knowledge of physiology and enthusiasm in science-related careers in Native American students. Biomedical scientists and students from University of Nebraska Medical Center, Nebraska Wesleyan University and University of South Dakota volunteered to hold the event. 224 participating students filled out pre- and post-event evaluation assessment, which helped to determine the effectiveness of the day of activities. Becker and his colleagues found out that the day of outreach activities

increased both students' self-perceived understanding of physiology and enthusiasm toward scientific careers.

*2. Loma Linda University (LLU) Summer Health Disparities Research Programs*[48]

The objective of outreach programs at LLU is to increase research self-efficacy in participants by providing them the opportunity to perform research and receive personalized mentorship and career development activities, such as education on health disparities. Salto and her colleagues (2014) compared the effect of two summer research programs on high school and undergraduate participants. They examined the Apprenticeship Bridge to College (ABC) summer research program for high school students and the Undergraduate Training Program (UTP). They found that both high school and undergraduate participants were willing to include research in their future career plans and both populations reported gains in laboratory skills and research self-efficacy. Both groups of students identified hands-on research and experiences with mentors to be most valuable. In conclusion, Salto and team reported that the summer research experience was highly effective for recruiting both high school and undergraduate students into STEM.

*3. Student Educational Enrichment Program (SEEP)*[12]

Created in 1978, the SEEP has aimed to increase the numbers of URMs in biomedical-related careers. The SEEP has four main objectives: (1) to better the knowledge of biomedical sciences, (2) to familiarize students with available educational opportunities, (3) to help figure out career goals, and (4) to support students with health

profession schools admission. The summer program recruits high school students, research apprentices, and college students for 8 weeks. Based on their obtained data, SEEP students had great success in getting accepted into colleges and professional schools. Cregler (1993) concluded that SEEP was able to recruit and retain students in the biomedical science path.

4. *Research Initiatives for Student Enhancement (RISE) program* [49]

Funded by the Centers for Disease Control (CDC) and Prevention Initiative at the Kennedy Krieger Institute, RISE aims to increase diversity in the public health workforce. RISE set goals to offer a mentored public health research experience for URM students; to increase enrollment of underrepresented populations in public health and health-related professional programs; and increase collaboration and community outreach among Historically Black Colleges and Universities, the Kennedy Krieger Institute and Johns Hopkins Bloomberg School of Public Health. Based on their questionnaire data, Belcher and McFadden (2015) found that the RISE program was able to help students fulfill the academic requirements for master's theses and dissertations, and that the program could attract and recruit students from diverse backgrounds.

5. *High School Summer Laboratory Research Apprenticeship (HSSLRA) and College Laboratory Research Apprenticeship (CLRA)*[33]

Merging data from the Association of American Medical College (AAMC) Pre-Medical College Admission Test Questionnaire (PMQ) and the Student Record system (SRS), Tai and his colleagues compared MD/PhD program students who reported having

prior research experiences at high school and college levels with those without research experience. They wanted to know: (1) if HSSLRA participants would have a higher chance of graduating from MD/PhD programs than those who did not participant in HSSLRA, and (2) if HSSLRA participation is associated with greater matriculations into MD/PhD programs among URMs. Their results indicated that students with HSSLRA and CLRA experiences had much higher odds of matriculating into an MD/PhD program than those with only CLRA and those without any prior research experience; this trend also applied to both African-American and Hispanic groups.

**Table 1. List of Programs for High School Students.**

| # of Participants | Names | Results |
|---|---|---|
| 16 | Medical Student Mentorship Program (MSMP)[36] | • All mentees reported success in the college application process and reported acceptance into a 2- or 4-year college/university<br>• 12 of 16 students responded to MSMP follow-up surveys<br>  ○ 10 majored in biology with pre-medical track<br>  ○ 1 studied nursing<br>• 1 pursued a major for physician assistant program |
| 23 (Year 2009-2010)<br><br>27 (Year 2010-2011) | Ypsilanti High School Recruitment Through Engagement Program[37] | • Both mentees and mentors expressed high level of interest in the lecture contents.<br>• Both mentees and mentors felt positive about the hands-on activities and demonstrations.<br>• Both mentees and mentors also reported to enjoy preparing for the |

| | | |
|---|---|---|
| | | health fair and the shadowing opportunities.<br>• Mentees in Year 1 agreed that the program was interesting.<br>• Mentees in Year 2 strongly agreed that program was interesting.<br>• Mentees reported that they were satisfied with their mentors and want to keep in touch with their mentors. |
| 26 | Reach One Each One (ROEO)[38] | • 24 (92.3%) of 26 enrolled in college<br>o 21 (87.5%) were in health science degree programs<br>o 16 (66.7%) enrolled in pre-medical curriculum<br>• 2 (7.7%) of 26 were starting college later in the spring |
| 29 | Project ENGAGES[39] | • All students reported that they were satisfied with overall program experience<br>• Networking opportunities, interactions with mentors, interaction with faculty advisor, and research assignment received the highest ratings.<br>• 97% reported that they were "satisfied" or "very satisfied" with their mentors.<br>• 72% of students indicated that they were "very satisfied" with faculty advisor interactions.<br>• Students indicated that laboratory experience was the most exciting aspect of the program.<br>• Students also reported having a better understanding of research skills. |

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| | | • 28 of 29 declared STEM majors on college applications.<br>• 1 of 29 joined the U.S. army. |
| 162 | PULSE[40] | • 52 (32%) former participants responded to the questionnaires<br>  ○ 81% reported that program participation affected their decision to pursue medical-/science-related career.<br>  ○ 67% indicated intent to obtain MD/PhD or post-graduate degree.<br>• 22 of 36 (61%) enjoyed simulation activities the most<br>• 25 of 36 (69%) indicated that they would have appreciated more simulation or more opportunities to do laboratory experiments with graduate students<br>• 35 respondents were in college at the time of the survey<br>  ○ 29 (81%) majored in science-related field<br>• 24 (67%) indicated desire to pursue PhD, MD or graduate degree |
| 220 | University of Maine Stormwater Management and Research Team (SMART) program[41] | • Of 125 former and current participants, 41% have been accepted or are enrolled in a secondary STEM degree program<br>  ○ 84% are female or URM<br>• 72% reported increased confidence in taking STEM courses |
| 405 (reported in 2007); 618 (reported in 2015) | Stanford Medical Youth Science Program (SMYSP)[21,42] | **2007**<br>• 99% admitted to college<br>• 81% attended 4-year college:<br>  ○ 57.1% majored in biological |

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| | | & physical sciences<br>○ 52% attending or graduated from medical or graduate school<br>○ 44.4% becoming or have become health professionals<br><br>**<u>2015</u>**<br>• 99% went to college<br>• Among those who completed college:<br>○ 47% were attending or completed graduate or medical school<br>○ 44% entered biomedical careers |
| 5113 | Inclusive STEM High Schools (ISHSs)[43] | • North Carolina<br>○ Higher percent of African American students in ISHSs took regular and advanced STEM courses than those in comparison schools.<br>▪ 210(55%) of 382 ISHS took calculus or precalculus compared to107 (24%) of 445 in comparison school.<br>▪ 271 (71%) of 382 ISHS took chemistry compared to107 205 (46%) of 445 in comparison school.<br>○ Teachers' expectation for post-secondary degree completion was higher among ISHS students.<br>• Texas<br>○ Hispanic and female ISHS |

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| | | students expressed a statistically significant stronger science identity.<br>▪ 2.42% (17 of 703) Hispanic ISHS students compared to 2.27% (26 of 1183) Hispanic students in comparison school.<br>▪ 2.35% (about 11 of 486) female ISHS students compared to 2.20% (20 of 907) female students in comparison school.<br>○ 2.77% (about 3 of 118) African American ISHS students expressed stronger math efficacy compared to 2.58% (about 5 of 191) students in comparison school.<br>○ 2.51% (26 of 1041) ISHS students reported perseverance in difficulty in a math or science class compared to 2.25% (40 of 1795) students in comparison school.<br>○ 88% (about 916 of 1041) ISHS students expressed interests in STEM career compared to83% (about 1489 of 1795) those in comprehensive school. |

**Table 2. List of Programs for Undergraduate Students.**

| # of Participants | Names | Results |
|---|---|---|
| 20 | Summer HIV/AIDS Research Program (SHARP)[44] | • 95% reported intent to apply to graduate school.<br>• Participants reported gains in understanding scientific methods and self-identification as researchers. |
| 55 | Minority High School Student Research Apprentice Program (MHSSRAP)[25] | • 100% matriculated to a college or university<br>  ○ 56% biology major<br>  ○ 15% liberal arts<br>  ○ 11% chemistry<br>  ○ 7% allied health disciplines<br>  ○ 11% others<br>• 29 (53%) graduated from college<br>  ○ 23 of 29 (79%) chose a medical or health science career<br>  ○ 17 of 29 (59%) matriculated into medical school<br>• 23 (41%) were still attending college<br>• Data were unavailable for 3 (6%) students |
| 120 RISE participants<br><br>295 matched controls | Research Initiative for Science Excellence (RISE)[45] | • RISE participants consistently expressed high intentions over time, while matched control students' intention declined over time.<br>• RISE students showed high degree of stability or positive growth in their intentions to pursue a researcher career, while matched control students showed relatively less stability and less positive growth.<br>• Only research experience, not |

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| | | mentorship, uniquely and strongly influenced the growth trajectories of students' intention to pursue a career as a researcher. |
| 768 | Meyerhoff Scholars program[46,47] | • 260 (34%) of 768 were still undergraduate students at the time of the study.<br>• 508 (66%) participants completed undergraduate study.<br>• 435 (86%) of 508 earned science or engineering bachelor's degree.<br>  ○ 379 (87%) of 435 attended graduate or professional programs.<br>• Students in Meyerhoff program were twice as likely to enroll in post-college graduate programs compared to 35 who were invited but declined the program to attend other institutions.<br>• Meyerhoff students were also twice as likely to earn science and engineering B.S. degrees as Asian, Caucasian, and non-Meyerhoff African American students with similar preparation and interests. |

**Table 3. List of Programs Targeting More Than One Educational Level.**

| # of Participants | Names | Results |
|---|---|---|
| 224 Middle and high school students | 1-Day immersive physiology experiment event[1] | **<u>Pre- and Post-Event Evaluation</u>**<br>• 64% increased to 69% of students who responded that they knew "a little bit" of physiology.<br>• 1% to 24% increase in student's |

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| | | self-perception of "knowing a lot" about physiology.<br>• 33% to 44% of students felt that science was "very interesting and fun."<br>• 50% to 12% of students indicated they did not know their level of interest or not interested in scientific career.<br>• 50.4% to 63.8% of students indicated being either "a little" or "very" interested in scientific careers. |
| 132 high school students<br><br>139 undergraduate students | Loma Linda University (LLU) Summer Health Disparities Research Program[48] | • 67% of high school (HS) and 90% of undergraduate (UG) students graduated college with STEM degree<br>• HS participants showed increase in intent for MD/PhD and PhD/Dr.PH after program participation.<br>• UG participants showed increase in intent for MD/PhD degree after the program.<br>• UG participants reported higher ratings of their perceived research skills than HS participants.<br>• Both HS and UG reported significant gains in research self-efficacy post-program. |
| 245 high school students<br><br>504 college students | Student Educational Enrichment Programs (SEEP)[12] | • 240 (98%) HS students entered college 1 year later.<br>• 400 (79%) college students responded to the questionnaire:<br>o 348 (87%) entered science occupations and/or professional schools.<br>o 179 (45%) matriculated to |

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| | | medical school. |
| 66 participants, composed of undergraduate students, graduate students and professional school students. | Research Initiatives for Student Enhancement (RISE) program[49] | • 47 (89%) of students' presentations were accepted at national scientific meetings (80% of students were reported to submit their research to meetings).<br>• Almost 14% of students were authors of peer-reviewed articles.<br>• 32 (48%) students completed master's degree.<br>• 14 (21%) students completed doctoral degrees.<br>• 13 (20%) students completed medical degree.<br>• 1 (2%) student earned nursing degree.<br>• About 63 (95%) students pursued education or career in public health and healthcare. |
| 236,432 MD/PhD students | High School Summer Laboratory Research Apprenticeship (HSSLRA) and College Research Laboratory Apprenticeship (CRLA)[33] | • Students with both HSSLRA and CLRA experience have 4.5x greater odds of matriculating into MD/PhD program than those without prior research experience.<br>• Students with only CLRA experiences have 2.79x greater odds of matriculating into MD/PhD program than those without prior research experience.<br>• Students with only HSSLRA did not have significantly greater odds of matriculating into MD/PhD program than those without any prior research experience.<br>• African-American (non-Hispanic) students in both HSSLRA and CLRA had 3.6x greater odds of |

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| | | matriculating into MD/PhD program than those without.<br>• African-American students with only CLRA had 2.82x greater odds.<br>• Hispanic/Latino students in both HSSLRA and CLRA had 5.37x greater odds of matriculating into MD/PhD program than those without.<br>• Hispanic/Latino students with only CLRA experience had 2.55x greater odds of matriculating into MD/PhD program. |

## DISCUSSION

Lack of precollege academic preparation often sets off a "domino reaction," leaving young people without the time and resources that help them enter a scientific career path[33]. In order to increase diversity, outreach programs were developed with the intention of supporting students' existing interests and increasing their confidence to pursue a career in a specific field. Early exposure programs claimed that their students are more likely to continue their career pursuit in the field of interest after program participation. Based on the 16 reviewed programs and ISHSs, I found that these programs were able to provide necessary resources, encouraged targeted students, and maintained students' interests in the field. For instance, an almost double percentage of students who attended a MD/PhD program reported being past participants in an HSSLRA compared to that of non-MD/PhD students[33]. Students with both HSSLRA and CLRA experiences were more than four times likely to matriculate into MD/PhD programs than those without research experiences[33].

## Commonality among Outreach Programs

Based on the prior studies, I found that programs with successful results have common features incorporated into their design. These activities captured and supported students' interests in the field. The following practices and resources are the common elements found in these successful programs:

1. *Stimulating, In-depth Learning Environments and Future Career Preparation Seminars*

Programs often aimed to create a stimulating learning environment for their participants, which included scientific lectures from field-specific faculty like physicians but usually deviates from traditional lectures by adding more discussion and encouraging active participation. These outreach programs also attempted to prepare students for a specific career by providing helpful information about particular career path and educating them on work of a particular career. There were noteworthy examples of classroom designs reported in prior research. The first example was the SMYSP that utilized Cognitive Apprenticeship and Situated Learning theories to develop their curriculum[50]. SMYSP offered classroom instruction that was informal and included a hands-on approach; the program supplemented didactic presentations with group discussions and peer teaching. The second example was the SMART program that required its high school students to present their work in public and participate in outreach activities, educating other younger students, such as those in middle and elementary schools, and the people in the community, to increase awareness within the

local community, as well as encourage K-8 students to pursue STEM[41]. Another notable example was the PULSE curriculum that offered interactive lectures and problem-based learning (PBL) cases[40]. Each 50-minute lecture taught students in a large group on core concepts that were emphasized using examples from various diseases. Small group sessions for PBL activities led by teams of two to three medical students followed the large group lectures. PBL sessions were designed to mimic medical school curriculum. In each session, students worked on a medical case by formulating a diagnosis, predicting laboratory results, and creating a management plan. One PULSE student commented that the program provided an introduction "to a plethora of medical terms, tests, and processes that give me a leg up compared with the rest of the people in my science classes." Another PULSE student commented that "the cardio unit was so well taught that I was incredibly far ahead compared with my other classmates in undergrad. It was a strong foundation that helped a lot"[40].

Successful programs also supported students by providing helpful information regarding graduate or professional training[42]. There were notable examples of future career preparation. The first example was the opportunity to tour a medical school offered by ROEO to learn more about the admission process and interact directly with medical students and hospital staff[38]. Similarly, Project ENGAGES offered professional development workshops that included research ethical training, diversity and inclusion training, presentation skills training, and college preparation such as application process and examinations[39]. Lastly, SHARP provided weekly seminars for its participants to learn about quantitative and qualitative research methods, responsible research conduct, good

practices in biomedical HIV prevention research, HIV disparities, and scientific writing and presentation skills[44]. SHARP also offered clinical shadowing opportunities for those who were interested in medicine, nursing and psychology[44].

Many of the programs incorporated interactive learning settings because these settings received positive feedback from participants and were claimed by research to be effective. Project ENGAGES participants mentioned that field trips and the professional development activities were useful for increasing college readiness and exposure to STEM careers[39]. A stimulating learning environment can create an excitement about the subjects, such as science and medicine. An SMYSP alumna commented, "Then the lectures, man those were some great lectures. I felt like I was in heaven, sitting in front of college professors and doctors. It was like a dream come true"[21]. Lectures could enhance and build on information students learned in their high school classes, but these lectures only exposed students to the content and were not sufficient for effective learning. Experimental-based learning, such as having simple classroom experiments, has been argued to help students understand complex concepts easier[51]. Active processing of information, such as allowing students to construct their own understanding of concepts, could lead to better learning[14]. Furthermore, active learning like group problem-solving has been shown to improve student performance in undergraduate STEM courses more than traditional lectures that teach by telling, especially for small classes[52]. In addition, outreach programs gathered students with common interests in STEM. The proportion of students with similar race, ethnicity, or gender was shown to be a factor that made students feel like they belong[6,53]. The feeling of belonging could have motivated students

to work together and brought enjoyment when completing the project. In-depth learning environment and increased excitement may help students stay more engaged in the lessons they were learning. Providing necessary information to help create a future plan is as important as helping students gain experience.

2. *Direct, Hands-on Participation*

All of the programs with successful results offered academic enrichment other than lecture-based classes such as hands-on projects. For instance, in the one-day physiological event, students were provided preserved sheep lungs with intact bronchioles and trachea in order to observe the expansion and elasticity of the lungs; they were also given balloons to study about tidal volume, expiratory reserve, and vital capacity[1]. SMYSP participants spent about 8 hours weekly in an anatomy laboratory dissecting cadavers[50], during which students observe, for example, arteriosclerosis by feeling the involved blood vessels and then discussing healthy diets[21]. SMART program offered summer hands-on activities that allowed students to build temperature and conductivity sensors[41]. During the summer, SMART participants were trained to use Pasco sensors to monitor and create a chemical profile of the local river, and they were also trained to use kick nets to collect macro invertebrates and learn to establish species diversity indices of a river assisting in the determination of water quality[41]. A research study on SMART program concluded that SMART hands-on activity supported and maintained students' interests as well as increased their confidence and chance to be part of STEM fields[41]. Project ENGAGES participants attended 4-week boot camp for hands-

on lab techniques and safety trainings essential for their later participation in the research projects[39]. The PULSE program offered hands-on activities that include an anatomy dissection session, simulation activities in simulation laboratory, histology laboratory sessions to learn to use microscopes and read slides, and research experiments with graduate students[40]. The RISE program, funded by the CDC, offered three types of research experiences: full-time 9-week summer research experience, extended graduate research experience (summer and 10 hours per week during academic year), and full-time 1-year post baccalaureate Bridge program[49]. RISE students were able to work on up to 2 research projects giving them a broad experience with research conduct and analysis. Participants from the Ypsilanti program organized a health fair at their high school[37]. They handled the advertising for the fair and all of the educational activities; the goals of this activity were to engage participants and to raise oral healthcare awareness in the community[37].

An important question one might ask would be why these hands-on research experiences enhanced academic persistence. Evidence suggests that hands-on activities were effective in engaging the students in the lessons and capturing their interests. Research found that hands-on STEM activities created and sustained positive STEM dispositions at middle and high school levels.[54] Research opportunities and project-based instructional approaches were known to enhance students' passions toward STEM, especially for females and URMs[55–57]. Based on their pre- and post-event evaluation assessments, Becker and his colleagues (2017) found that activity-based learning opportunities led to an increase in both scientific knowledge and interest in scientific

careers[1]. They reported a decrease in numbers of students who initially reported that they did not know if they were interested in a career in science, as well as an increase of interests in scientific careers from 50.4% to 63.8% after the event[1].

Moreover, studies had shown that participation in research intensive programs could help students develop or reinforce a cognitive scheme for a career as a researcher, leading to a higher self-efficacy. Based on the analysis of 53 studies of research apprenticeships, Sadler, Burgin, McKinney, and Ponjuan (2010) found that research experiences boosted interests in science careers and self-efficacy for research skills[58]. Based on their quasi-experimental research, Knezek and his colleagues (2013) concluded that hands-on STEM projects improved students' content knowledge and their perceptions about STEM[59]. Similarly, Charney and his colleagues (2007) reported that high school students who engaged in the complex aspects of research, such as analysis, demonstrated gains in scientific reasoning[60]. Project ENGAGES participants reported that laboratory experience increased their interest in science and bettered their understanding of the work of engineering and biotechnology scientists[39]. It also boosted their curiosity and self-confidence. One participant commented, "The most exciting thing is I really feel like I'm immersed in the research culture now. And that's progress, like when you get wiser and mature! I feel like the same thing is happening to me in lab. So that's the best thing this summer"[39].

Earlier research also demonstrated that self-identity as a scientist and the degree to which the student values the objectives of science account for the persistence effect[61]. Merolla and his colleagues showed that proximate social structures can lead to a change

in identity[62], which meant that participating in a research training program could promote students' identities as a scientist. The change in identity could sustain students' motivation to pursue a scientific career. Increasing the likelihood for students to engage in academic experiences, such as participating in undergraduate research and involvement in academic organizations, had been suggested to improve STEM persistence in URMs[34]. Hands-on activities like a research project can support students' self-efficacy and help students visualize themselves in a particular role, which potentially lead to interests and pursuit of the activities related to those interests.

*3. Strong Mentorship and Long-term Support*

Studies reported that some students were not aware of mentored research options when they applied to college[63]. Research training and experience alone might not be enough to sustain long-term interest in research careers. Effective programs usually provided both hands-on activities and apprenticeships with role models, such as scientific researchers and health professionals. Strong mentoring also referred to proving long-term support, such as receiving encouragement during difficult times, letters of recommendation for colleges and future jobs, identification of scholarships and research opportunities, and any career advice. Research has shown that the integral parts of outreach programs that recruited and retained URM students in STEM included a focus on student-centeredness, community building and collaboration[64]. Project ENGAGES participants were matched with their research mentors through a "speed-dating" method. Mentors sat at tables with their names, and each student spent 4 minutes of interview time

talking to each mentor before rotating to another mentor; at the end, both research mentors and scholars list their preferences[39]. Each PULSE participant was paired with one medical student mentor who was required to contact his or her mentee by email twice monthly and in person at least once during the semester. The mentor provided guidance with course materials and college or career plan, and each mentor was evaluated by their mentee at the end of the program[40]. LLU summer program participants identified their experience with a mentor as one of the most important components of the program[48]. Similarly, SMART participants indicated that having a mentor was the most valuable factor for their motivation toward STEM[41]. 82% of female students and 78% of URM students in the SMART program strongly agreed that having a mentor was the strongest factor for their motivation[41].

Immersive educational programs are especially critical for those who do not have access to connecting with individuals in the sciences and engineering[33]. Some high schools lack counselors to provide guidance on scientific and health-related careers or college plans, which can contribute to the decline of interest in the field, especially for those without role models in families. Having a mentor can help familiarize students with the opportunities available for each career path. Programs should offer student opportunities to hear from those who know what it takes to be successful[33]. Direct support from academic mentors can help students stay focused on their interests. Supportive mentors can influence students' beliefs in their own abilities[65]. SMYSP offered personalized college and career advising, which helped motivate and create self-confidence[21]. SMYSP participants received college and career guidance during their

undergraduate and later years, such as financial advice and mock interviews for medical school[50]. One SMYSP past participant stated, "One thing I remember strongly was our counselor saying that it didn't matter where we came from, how much money we had or didn't have, or any other obstacles we faced socially, but if we worked hard enough and had a solid plan then we could go to college and be whatever we wanted to be because we were bright students and nobody could ever take that away from us"[21].

Long term support from a mentor might mitigate some challenges that students face. The types of opportunities, experiences, and support students receive during college years are as important for the progress through the STEM pipeline as the pre-college experiences[66,67]. Long-term support is important for those without mentors or role models. An SMYSP alumnus who later attended medical school noted, "SMYSP accepted me when I was a struggling kid with failing grades and part of a gang. It supported me then and for years to come"[21]. Prior research has suggested that mentored students perform better academically and have higher attendance and satisfaction. Witkow and Fuligni (2011) showed that failure to get good advice on career and educational plans can influence students' future educational performances[68].

Foertsch, Alexander, and Penberthy (2000) compared summer programs at 15 Midwestern research universities and reported that the factor in determining success of the program was the quality of relationship with the mentor, even with limited contact hours[69]. The SMART program encouraged close relationships between mentors and students by having mentors meet students in their community center and using a learning topic integral to their native culture and economy[41]. The SMART project team also

provided support during the academic year with site visits, phone, email, and video-conferenced meetings, as well as online resources via the project website[41]. SMYSP provided post-program support through workshops and reunions. For instance, all participants who were applying for college returned each fall for a day of college admissions and career advising workshops; participants also regularly received emails and mail about scholarship, research internship, and other health career opportunities[21]. SHARP provided opportunities for one-on-one mentorship on a research project by assisting with data collection, secondary data analysis, and literature review[44]. To ensure that students have sufficient oversight during the research experience and to lessen the faculty's concern of committing additional time to students, SHARP encouraged assemblies of mentor teams that consisted of junior faculty and research staff. The teams could facilitate meetings with students while preserving time for senior faculty to focus on teaching and personalized coaching[44]. Furthermore, programs like SHARP were aware of the importance of a mentor's awareness of unconscious biases and the negative impacts on microaggressions on students' experiences. SHARP recognized that mentors should be aware that stereotype threat can negatively influence undergraduate students' performances. In other words, they had to be aware of the risk of confirming a negative stereotype about one's social group. The program also encouraged mentors to work with students in an attempt to raise awareness of the tension between students' cultural norms and those within the scientific community. SHARP had mentor orientation that incorporated self-assessment and case-based discussions to bring up issues that affect URM students' experiences[44]. Medical students seem to be ideal mentors because they

are relatively close in age to high school students and can provide a comfortable and engaging educational environment[40].

Structured mentored research has been known to influence future education and career trajectories[70–72]. An impactful mentored research experience during the early formative years, such as undergraduate and post-baccalaureate, can influence students' impressions of science and solidify their lifelong passions. The social cognitive career theory (SCCT) provides another explanation for why mentorship is necessary. SCCT posits that a person's self-efficacy beliefs can affect their interests, which in turn affects their academic or career path[73,74]. In other words, SCCT posits that students' sense of self-efficacy ("Can I do this?") and outcome expectations of their future careers ("If I do this, what will happen?") drive their career-related interests and goals, as shown in Figure 3[73].

SHARP utilized SCCT to design its components[44]. The program boosted students' self-efficacy by allowing opportunities for students to succeed and provoking positive feelings as they considered future career success. SHARP scheduled times for sessions in which students received encouragement and constructive feedback from their mentors and peers; SHARP participants also had the opportunity to show their work publicly at a symposium and receive recognition from leaders at the SFDPH[44]. Outcome expectations can be supported by frequent contact with successful role models. Receiving support and advice from trusted mentors can boost students' confidence and motivation along their career journeys. A program design based on SCCT appeared to be a factor that led to successful results.

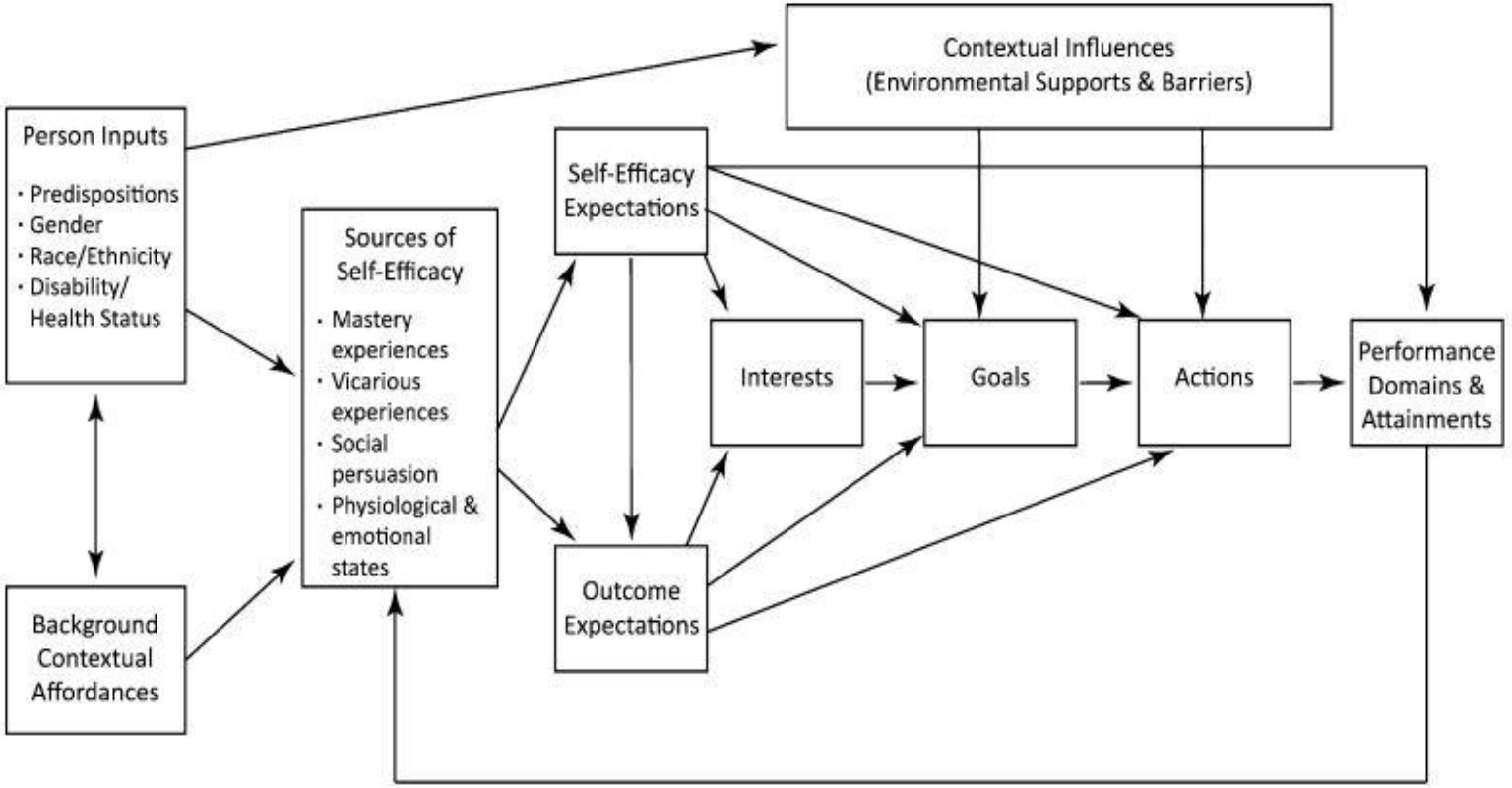


**Figure 3. Adapted diagram of processes underlying Social Cognitive Career Theory (SCCT)**. The schematic illustrates the relationships and influences among different factors leading to the development of career interest and goal based on SCCT.

**Source**: Fuchs, J., Kouyate, A., Kroboth, L., and McFarland, W. (2016)

4. *Partnerships Between Universities and Other Field-specific Facilities, Such As Hospitals and Clinics.*

Many effective programs partnered with facilities to provide exposures in real-life settings, as well as tools or other resources that prepared students for their future careers. For example, SMYSP offered exposure to college life[21], and SEEP participants lived on campus during the duration of the program[12]. These high school students had the opportunity to experience the life of college students. SMYSP participants lived in a residential house with a computer laboratory set up on Stanford's campus where faculty, medical students, and health professionals frequently visited for informal discussions and mentoring[21]. SMYSP also arranged educational activities that involved participation in community[50]. SMYSP participants spent 2 days per week in the hospital, where they worked with physicians and other health professionals. Working side-by-side with experts allowed students to observe and practice skills and receive constructive feedback. For instance, SMYSP students learned about forensic science during their placement in the morgue[21]. Furthermore, through partnerships SMYSP was able to introduce its participants to cultural events and other universities and laboratories through weekend field trips[21]. Likewise, SMART program participants stayed at the college dorm and worked in university labs for science and engineering training[41]. SMART participants worked with water district officials or scientists to collect data on a weekly basis, and they also connected with STEM professionals in water and engineering in government, private firms and non-profits[41]. SHARP offered summer research experience at the San Francisco Department of Public Health (SFDPH)[44]. Being a health department, the

SFDPH introduced students to the opportunities of having a research career in public health settings and the wide range of federally-sponsored, investigator-initiated, and clinical trial studies[44], exposing students to research-related careers outside of academia. Similarly, through partnership, ROEO students were allowed to shadow one of the partnering medical disciplines for half a day over a 6-week period under the supervision of attending physicians or residents on-call[38]. ROEO students were taught hands-on surgical skills and trauma and injury prevention by the surgical team, and they were allowed to observe operations and professional interaction with both the surgery and anesthesiology team. They also were exposed to real-time acutely injured trauma patients and acutely ill surgical patients who presented at the emergency department[38]. MSMP recruited principal investigators from the Department of Basic Medical Sciences to provide laboratory shadowing opportunities for students who are interested in basic and translational research[36]. PULSE partnered up with affiliated high schools and colleges to organize college fairs that open to all students and organize career symposia that include members from various disciplines, such as physical therapy, nutrition, pharmacy, and dentistry[40]. A program with established partnerships with hospitals or research facilities can provide more resources for students, especially those from ethnic minority and low-income groups who attend high schools that have little to no collaboration with community-based health facilities or health professionals at universities.

5. *Incentives*

Another common characteristic seen in most successful outreach programs was the promise of incentives. Summers and Hrabowski (2006) listed merit-based financial support as one of the factors that allowed the Meyerhoff Scholars program to achieve its goals[46]. MHSSRAP provided stipends to students while working in the lab during the summer[25]. SEEP participants received biweekly stipends and those who completed the program with a B average grade received a scholarship[12]. SHARP, too, was a paid summer internship, with the aim to lessen the financial pressure to work during summer and concentrate fully on the program[44]. Project ENGAGES offered a paid hourly wage that is higher than minimum wage as incentives to its participants to avoid finance as being a selection factor[39]. Partner high schools of Project ENGAGES also provided students free lunch due to their socioeconomic status[39]. MSMP obtained approval for medical students to receive volunteer credits through the program as they serve as mentors and for high school students to get internship credits as incentives to participate in the program[36]. When attending PBL sessions, PULSE participants took period quizzes and a final examination. Those who receive >80% final average grade receive letters of recommendation to be used in college applications. PULSE students could also request two college course credits offered by Pennsylvania State University[40]. The RISE program, funded by CDC, received stipends for all students and covered costs of health insurance for uninsured students[49]. RISE also provided housing and transportation for out-of-state students during the summer[49]. Minority families are often in the low economic poverty line. Some students must find a part-time, if not full-time, job to support their families. Students from disadvantaged backgrounds can be dissuaded from considering higher

STEM education like graduate studies due to the prospect of accruing substantial student debt[75]. Incentives, such as stipends or school credits, can reduce financial burdens on students while ensuring that they pursue their educational interests.

*6. Other Potential Factors*

Other factors that may have helped program successes were small student-to-staff ratios and the program durations. One limitation on the programs seemed to be the large number of students and little individualized mentoring. SMYSP had a 2:1 student-to-staff ratio and provided continuing personal mentoring[21]. The small ratio of students to staff appeared to help ensure that each student received the most possible support to perform to the best of their ability. Furthermore, a follow-up study found an association between participation in on-campus academic year research and substantial increases in STEM PhD pursuits, suggesting that the structure and intensity of the research experience matter[76]. Therefore, the ratio of student to mentor and the program duration were potential components that made programs effective. Although most programs reviewed in this paper were at least one summer long, further investigation is still needed to determine the true effect of program size and duration on students' learning processes and motivations.

**Evaluation of Boston Area Health Education Center (BAHEC) Programs**

In this section, I will discuss the programs by BAHEC and provide suggestions for the program development to promote better outcomes based on the common factors previously stated. The Boston Area Health Education Center (BAHEC) is a health careers

program under the Boston Public Health Commission's Child and Adolescent Health Division that aims to increase diversity in the medical workforce. The main objectives of the program are to create interest, increase knowledge, and build confidence in young scholars to pursue health-related careers. The program targets middle and high school students from Boston, especially those from underserved areas. BAHEC supports different groups of students during the summer and academic year. About 60 students during the academic year learn concepts of public health, such as determinants of health and health equity. They also are able to enroll in field-specific courses, like Nursing, Physical Therapy, and Emergency Medical Services. During the 6-week summer program, nearly 90 students take classes that prepare them for the fall semester and attend workshops on nutrition, fitness, and healthy relationships. Through partnership with hospitals, community health centers, and public health professionals, BAHEC also allows students to learn from field-placement experiences.

Based on the current program design and activities, BAHEC should be able to build and sustain students' interests in the healthcare field. Due to the incorporation of hands-on activities in classes or workshops, students should find lessons to be informative and engaging. One helpful addition to be included in the program would be mentorship. The program is predicted to be more effective if students have mentors with whom they receive guidance and feedback. Offering both hands-on activities and mentorship over a period of time appears to be helpful in motivating students to pursue the field. The results of the Ypsilanti program and other programs support this idea. One mother of the Ypsilanti participant mentioned to its program coordinator that her

daughter “had never been interested in academics but now was determined to go to college”[37].

The quality of mentorship is critical. Additional training and support for mentors may provide the most effective mentorship. Studies found that effective mentors are those who have strong communication skills, are willing to clarify expectations of mentor/mentee relationships, provide constructive feedback, and recognize differences between mentor and mentee[77,78]. Avent and his colleagues (2018) through their analysis of Project ENGAGES found that diversity and inclusion training was important for integrating African American students into the demographics of Georgia Tech and for mentors to understand their own inherent biases[39].

However, offering one-on-one mentorship would be understandably difficult due to the large numbers of students in the BAHEC program. Perhaps having an advisor responsible for a certain number of students is more feasible. Organizing weekly or monthly group meetings in which an expert on a particular field comes in to speak and share experiences would be helpful as well. On Saturday mornings, Ypsilanti mentees and mentors shared breakfast and snacks, allowing opportunities to connect on a personal level[37]. Many mentors like those in the Ypsilanti program, for example, were from URM groups and LI backgrounds, and were willing to share how they overcame obstacles. Students may find it easier to connect and see mentors who come from similar backgrounds as role models.

In terms of examining the effectiveness of BAHEC programs, contact with participants should be maintained over time. Winkleby (2007) reported that her success

in tracking alumni of SMYSP for up to 18 years was due to the strong relationships developed among the program staff, students, and their families, ensuring detailed contact information and diligence in follow-up[21]. Perhaps a reunion or online group meetings can be arranged for networking opportunities and continuing contact with past participants.

## CONCLUSION

Success to increase diversity depends on addressing both academic and community issues. At the undergraduate level, administrative efforts and resources are needed to attract high-achieving minority students and prepare them for STEM courses. At the high school level, exposure to possibilities in career fields to stimulate or sustain interest is important. Factors that contribute to the decline of interest in the field include menial personalized college and career guidance, no long-term support, no direct exposure to college life or health professionals, and few links with established facilities. Based on this literature review, it has become more certain that successful programs share common attributes. Student outreach programs to promote interests in STEMM usually consist of classroom-based lessons, hands-on activities, and student-mentor partnerships over a period of time. These factors provide opportunities for students to work on actual on-going projects and prepare them for their academic training. Experiences during outreach programs also give students time to establish the necessary academic background for future success.

Future studies should perhaps examine the extent to which the above-mentioned factors contribute to the effect of retaining URMs in STEMM. Quantitative data and

statistical analyses are also needed to confirm that these factors contribute to success. Little is known about the specific behaviors, paths, and contexts of successful mentoring. Future studies investigating which mentoring type, and why and when to use each mentoring type can be helpful because a better understanding of mentorship may help faculty and staff improve the effects of mentoring. In addition, future studies can identify factors that may further dissuade students from pursuing the STEM path. Lastly, it would be valuable to see the impact of program duration to determine if a summer or academic year program would be more effective in providing support and sustaining students' interests.

**Limitations**

There are limitations in this paper. The programs with successful results are usually a case report with longitudinal data, and most studies lacked a comparative group not exposed to the program, which created a limitation on the data for most programs. Selection bias is another factor that may contribute to the successful results. Factors measuring pre-existing motivation that can influence initial participation in outreach programs were not included in the data set. Participants in programs might have been high achievers and were already highly motivated before attending programs. The exception was the LLU program study that measured changes in research intent, skills, and self-efficacy using participants' baseline values as controls and focusing on the differentials account for selection bias[48].

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