JOURNAL of STEM OUTREACH

Vol. 8, Issue 1, October 2025

Outcomes of a Multi-Year Biomedical Research Program for High School Students

Andrea Giuffrida[1], Irene Chapa[2], Y. W. Francis Lam[3], Kristen La Porte[2], Linda M. McManus[4], and Anthony L. DePass[5]

[1]Department of Medical Sciences, Western University of Health Sciences, Pomona, CA; [2]Office of Recruitment and Science Outreach and Departments of [3]Pharmacology and [4]Pathology and Laboratory Medicine, University of Texas at San Antonio (formerly University of Texas Health Science Center at San Antonio), San Antonio, TX; and [5]DePass Academic Consulting, Freehold, NJ

Keywords: High School Research Program, Mentorship, STEM Outreach, STEM Careers, College Preparation, Broadening Participation, Underrepresented Youth

Publication Date: October 27, 2025

DOI: https://doi.org/10.15695/jstem/v8i1.13

ABSTRACT: The Voelcker Biomedical Research Academy (VBRA) provided an opportunity for high school students to engage in mentored biomedical research activities with a faculty investigator. The three-year program, utilizing a Social Cognitive Career Theory framework, included tiered mentoring and a collegiate component in preparation for biomedical science careers. Nine cohorts of 20-22 students from public, private, or charter high schools were admitted to VBRA in 2009—2017. Applications (n=909) were submitted by freshmen in the Fall, top-ranked meritorious applicants (n=486) were interviewed in the Spring, and VBRA Scholars (n=191) entered biomedical research training in June. The demographics of entering students reflected the population of San Antonio, Texas, which is primarily Hispanic. While some students attended private or parochial schools, the majority attended public high schools, and had parents with advanced degrees. Most Scholars (79%) matriculated at R1 institutions for undergraduate studies, and over 70% either completed advanced STEM educational programs or gained employment in STEM-related careers. Although more VBRA Scholars were mentored by Assistant Professors, a smaller percentage of these Scholars matriculated into R1 institutions than Scholars mentored by Associate and Full Professors. Overall, this multi-year mentored research education and training experience for high school students provided an effective biomedical research ecosystem that contributed to a sustained interest in STEM-related careers.

INTRODUCTION

Pre-college pipeline programs in science, technology, engineering, and math (STEM) have been offered by institutions of higher education to address the increasing demand for a well-trained workforce and facilitate the recruitment of students from diverse backgrounds. In addition, many stakeholders—including academia, business, industry and biotech enterprises—are concerned that the shortage of STEM-trained professionals may negatively impact the competitiveness of our nation globally (National Science Board, 2022).

Despite efforts to increase the number of undergraduate students in STEM, the approaches to engage and keep them interested in completing advanced degrees at graduate and professional schools remain challenging. Indeed, the high attrition rate among undergraduate students who enter STEM disciplines, as well as the low number of underrepresented minorities among them (Fouad & Santana, 2017; National Science Foundation, 2023), underscores the difficulties in sustaining students' interests and providing adequate academic support. Contributing factors to undergraduates' attrition in STEM include, but are not limited to, lack of early exposure to STEM subjects, inadequate teaching methods, lack of role models, socio-economic and cultural barriers, limited understanding of career opportunities, insufficient extracurricular support, and psychological/behavioral factors (*e.g.*, disparities in accessing STEM education and/or employment, etc.) (Fouad & Santana, 2017; National Science Foundation, 2023; Noonan, 2017; Funk & Parker, 2018). In addition, undergraduate students often lack experience in an active research environment, despite the recognized importance of this factor in shaping college major selection and career choices (Estrada et al., 2018).

Comparable to undergraduates, most high school students have limited research exposure at a time when they contemplate future career paths. High school student participation in out-of-school science-related activities and STEM programs has proven instrumental in developing interest in scientific disciplines and influencing college degree choices (Dabney et al., 2013; Sahin et al., 2017; Ahmad et al., 2021). In particular, hands-on mentored research of varying duration, as well as self-efficacy and identity as a scientist, have been shown to reinforce student engagement in STEM and the pursuit of careers in science (Cantor et al.,1998; Chemers et al., 2011; Salto et al., 2014; Schultz et al., 2011; Winkleby, 2007).

In line with these observations, a multi-year biomedical research training program for meritorious high-school students was developed at UT Health San Antonio, a public academic health science center within the University of Texas System. This program, named the Voelcker Biomedical Research Academy (VBRA), was launched in 2009 with grant-funded financial support from the Max and Minnie Tomerlin Voelcker Fund, a local foundation supporting biomedical education, training, and research in the San Antonio area. San Antonio is a minority-majority city (approximately 60% of its residents are Hispanic-Latino) with significant socio-economic disparities and problematic educational outcomes. The healthcare and bioscience sectors are the largest regional economic contributors in the city (San Antonio Chamber of Commerce, 2022), underscoring the importance of training the future biomedical workforce to sustain and grow the local life sciences industry.

The VBRA had, as its underpinnings, a Social Cognitive Career Theory (SCCT) framework (Lent et al., 1994). Within this context, learning experiences were designed to strengthen participants' self-efficacy and outcomes expectations, ultimately enhancing their performance and growth as scientists. Such experiences also served to influence and develop interests that informed both short-term academic decisions and long-term career goals, leading to impactful outcomes and attainments, whether as clinicians or scientists. For example, first-year VBRA Scholars toured research laboratories and practiced foundational lab techniques to gain experience and build confidence in their scientific abilities (self-efficacy). Meanwhile, activities such as one-on-one mentorship and discussions of real-world scientific breakthroughs were designed to help students appreciate the tangible benefits of a science career, thereby fostering positive outcome expectations. Together, these gains in self-efficacy and outcome expectations were intended to enhance students' science identity and sense of belonging within the scientific community, both of which are key factors that support long-term persistence in STEM fields.

Consistent with this theoretical framework, the VBRA program followed a two-fold design. The earlier experiences exposed students to research scientists, laboratory environments, and the foundational methodologies of biomedical research. Beyond this introduction, the program provided "hands-on" mentored research experiences that allowed the students to engage in science as professionals do, with ongoing guidance from mentors who were at various career stages (graduate students, postdoctoral research fellows, and established investigators). These experiences not only helped students build their identity as scientists, but also gave them a deeper understanding of the pathways to professional practice. As a result, participants became more informed than their peers and actively generated outputs that demonstrated productivity, including stage-appropriate presentations and publications.

In alignment with this framework, the evaluation measures focused on self-efficacy, science identity, and sense of belonging to the intellectual and social environments that characterize high-powered training programs. In accordance with SCCT, we anticipated that increases in self-efficacy would also strengthen each Scholar's identity as a scientist and their sense of belonging within the scientific community, thereby encouraging persistence in STEM. Additional outputs included academic performance, with students demonstrating greater "maturity" in both the practical application and understanding of knowledge covered in their classes, as well as in their overall experience of science. Students also gained valuable insights into the processes and activities that result in professional success in the biomedical sciences, while building the confidence and skills needed to excel in these spaces.

The VBRA integrated hands-on research experience in biomedical sciences over three years for each cohort. All programmatic activities were designed to: (a) deepen knowledge in biomedical disciplines in real-world settings, (b) help students identify their academic interests and career paths, (c) offer research experiences to increase student competitiveness for college admissions and scholarships, (d) provide professional networking opportunities, and (e) boost students' confidence and resilience. This multi-year high school experience in biomedical research increased STEM-related advanced education as well as career outcomes. Here we provide a detailed description of programmatic components and outcomes over the lifetime of VBRA through 2017.

PROGRAM OVERVIEW

The VBRA entailed a partnership across multiple administrative offices, including the Office of Recruitment and Science Outreach (ORSO), Office of the Vice President for Research, Office of the President, and Office of Postdoctoral Affairs (OPA). The design of our research training program was primarily informed by our extensive experience with graduate students in the biomedical sciences and running

STEM outreach initiatives as well as on pre-existing evidence. Indeed, many features of the VBRA align with best practices described in the literature for high school research training programs. For example, the VBRA's multi-year structure, emphasis on hands-on research, and multi-tiered mentoring model are similar to those of other successful pre-college STEM programs (e.g., Rohrbaugh & Corces, 2011; Rosenbaum et al., 2007; Winkleby, 2007).

Research activities by VBRA students (Scholars) were carried out in the laboratories of Faculty Mentors where Scholars learned the framework of ongoing research efforts and acquired relevant laboratory techniques for their research project. Throughout all three years, Scholars also participated in didactic and enrichment activities designed to support training in contemporary biomedical research disciplines and to develop their communication and leadership skills. In addition, they received guidance about future college selection and applications. The number of new Scholars varied from year to year with approximately 21 new positions per year depending on the availability of funds. Thus, the VBRA averaged a total of 60 participants per year (given the 3-year duration of the program).

Students received a summer stipend ($500, $750, or $1000, in years 1, 2, or 3, respectively), and Faculty Mentors had access to $1,000 per year to cover the costs of student-related research supplies.

Student Recruitment and VBRA Scholar Selection. The recruitment and selection of VBRA Scholars was a comprehensive process encompassing: (a) advertisement of the VBRA program across the San Antonio metropolitan area through both surface and electronic mail to principals and directors of science programs, (b) advertisement at science fairs, and (c) VBRA staff visits at high schools to deliver information about the program and application process to teachers and students. Details were available on the VBRA website.

During staff visits at high schools in the Fall semester, guidelines for the application and selection of VBRA Scholars were provided. VBRA Scholars from participating schools served as program ambassadors, joining VBRA staff to provide informational sessions about the Academy. Applicants were rising high-school sophomores of at least 15 years of age at the time of VBRA enrollment and with a strong interest in the biomedical sciences. The nominating official from each school provided a description of their criteria and process for selecting nominees; this information did not impact any aspect of the VBRA review process.

The application included a personal statement by the nominee, official academic transcripts, letters of recommendation from two teachers (at least one science teacher) and evidence of participation in extra-curricular activities (including volunteer efforts). All application packages were screened for completeness and then ranked by the VBRA leadership (Directors of ORSO and OPA, Vice President for Research, VBRA grant co-PIs) taking into consideration an interview with the VBRA Admission Committee; this committee was comprised of UT Health San Antonio faculty (including current and former VBRA Faculty Mentors), as well as postdoctoral research fellows and advanced graduate students (Junior Mentors).

Each applicant was interviewed by three committee members. Written comments and numerical scores addressed the review criteria, which encompassed the applicant's academic record, general scientific knowledge, communication and interpersonal skills, motivation to conduct research, commitment to participate in VBRA activities, leadership and confidence, and evidence of self-determination and work ethic. For a given applicant, the numerical scores were averaged among all reviewers; this final score was used to rank and select the finalists.

Following Scholar enrollment in the program, the equitable assignment of students to mentors was carried out through student interviews with participating faculty members. Post interview, both students and faculty mentors ranked their choices, which were then used to assign students to mentors. Prior to the interviews, students were introduced to various scientific disciplines, lab technologies, and research approaches, allowing the VBRA director to better understand their interests and guide them in choosing a faculty research mentor. Additionally, pre-interview peer mentorship provided deeper insights into the research environment at UT Health San Antonio.

VBRA Scholars were selected in the Spring for entrance into the VBRA program in June of the same year. The accepted candidates committed to 35-40 hours/week for a minimum of seven weeks during the summer months. Additionally, Scholars were encouraged to participate in educational enrichment activities throughout the school year.

Historical Adjustments to the VBRA Program. Prior to 2016, all VBRA application components (personal essay, official transcripts, and letters of recommendation) were submitted as hard copy documents. This changed in 2016 when a secure online system was implemented to collect individual application components. The system expedited processing, streamlined record-keeping, and facilitated application review and the subsequent collection of comments and scores following in-person interviews.

Prior to 2017, an open, self-nomination process was utilized. This was modified to limit the number of applications from each school to three nominees per year. Restriction in the number of applications from a given school addressed administrative and programmatic challenges associated with growing numbers of self-nominations. Additionally, in 2017, the program implemented ACT/SAT test preparation activities (e.g., practice tests and strategy sessions) to enhance Scholars' performance in college entrance exams.

Although the VBRA research education and training goals were unchanged throughout all years, the 3-year plan was reduced to a 2-year experience in 2018 and 2019 due to budgetary and logistical constraints. Consequently, applicants for 2018—2019 were high school sophomores who first engaged in research training in the summer as rising juniors. Beginning in 2021, after a one-year interruption in admission of new scholars due to the SARS-CoV-2 (COVID) pandemic, the VBRA returned to a 3-year research training format. However, the application process and components remained unchanged among all years of the program (2009—present). Given the considerable programmatic changes beginning in 2018, findings in this paper describe program features and outcomes for VBRA cohorts from 2009 to 2017.

Curriculum. Each cohort of VBRA Scholars participated in the program for three years. The curriculum included multiple components, which are described below.

Year 1. The Year 1 curriculum consisted of weekly modules that combined lectures provided by Faculty Instructors and laboratory exercises designed to introduce fundamental concepts of contemporary biomedical science (summarized in Table 1). During the first week, all Scholars received an orientation about VBRA programmatic activities, which included seminars on safety in the laboratory and across the university campus, and team building exercises. Special sessions enhanced Scholars' understanding of the broader biomedical research ecosystem at UT Health San Antonio. These included: medical terminology, digital resources and training to access scientific literature, team science, research funding, undergraduate and graduate research training, rigor and reproducibility, and scientific integrity. Additionally, Scholars participated in field trips to local research institutes and biotech companies, attended weekly journal clubs to critically evaluate scientific articles, and detailed their VBRA experiences in daily journal entries. Faculty Instructors included UT Health San Antonio faculty as well as postdoctoral research fellows and advanced graduate students.

Years 2 and 3. During the second and third year, Scholars primarily focused on research in the laboratories of their Faculty Mentor (Table 1). Scholars presented and discussed their research projects at their respective lab meetings and also participated in: (a) *Throw-back Tuesdays*, an informal luncheon event planned to reconnect Scholars with their cohort and to continue their leadership development as young professionals, and (b) *Peer-to-Peer Mentorship* sessions

Table 1. *VBRA programmatic components.*

Activities	Year 1	Year 2	Year 3
Educational	• 1st week: orientation & safety training; team building exercises • Weekly modules (lectures and laboratory techniques) • Review of genetics/genomics, anatomy/physiology, microbiology/immunology, cancer biology, aging, neuroscience, pharmacology, population health, bioinformatics/big data, precision medicine, and technology commercialization • Special sessions; e.g., medical terminology, digital resources and training to access the scientific literature, responsible conduct and rigor and reproducibility in research • Weekly Journal Club to analyze, discuss, and critically evaluate scientific articles	• *Throw-back Tuesdays*—weekly luncheon to reconnect Scholars with their cohort; continued leadership development • Mini-course: *7 Habits of Highly Effective Teens* based on Covey (2013) to improve self-image, achieve goals, build friendships, and manage peer pressure	• *Throw-back Tuesdays*—weekly luncheon to reconnect Scholars with their cohort; continued leadership development • *College Connections*—workshops with VBRA Alumni regarding the transition from high school to college
Enrichment	• Welcome Dinner—introduction to program for Scholars and parents • Tours/field trips at local research institutes, healthcare organizations and biotechnology companies • University lectures by high-profile scientists Holiday Reception for Scholars and Alumni	• University lectures by high-profile scientists • Holiday Reception for Scholars and Alumni	• University lectures by high-profile scientists • Holiday Reception for Scholars and Alumni
Mentorship	• *Peer-to-Peer Mentorship*	• *Peer-to-Peer Mentorship* • Meetings with Faculty Mentor, Junior Mentors, and laboratory staff	• *Peer-to-Peer Mentorship* • Meetings with Faculty Mentor, Junior Mentors, and laboratory staff
Research	• VBRA research seminars • Interviews with potential Faculty Mentors • Select Faculty Mentor • Develop research project • Prepare research poster and present at *VBRA Graduation and Science Symposium*	• VBRA research seminars • Research activities with Faculty Mentor • Lab meetings • Biomedical specialty research seminars	• VBRA research seminars • Research activities with Faculty Mentor • Lab meetings • Biomedical specialty research seminars • *VBRA Graduation and Science Symposium*

(see below). Scholars also were encouraged to volunteer in community service activities, including helping at the local food bank and participating in science outreach events at local middle and high schools.

A unique component of the second year curriculum was the mini-course, *7 Habits of Highly Effective Teens*. This course, based on the book by Sean Covey (Covey, 2013), provided guidance to help Scholars improve their self-image, achieve goals, build friendships and manage peer pressure.

During the third year, VBRA Alumni presented workshops termed *College Connections* to graduating Scholars, sharing their insights regarding the transition from high school to college and discussing perspectives on college majors and career choices. At the end of the third year, all Scholars wrote a summary of their research projects, and some were selected to provide an oral presentation of their work at the *VBRA Graduation Ceremony* (see below).

Additional Programmatic Activities. Several activities were designed to enrich the Scholars' experience.

Welcome Dinner. At the beginning of the summer, a formal "welcome dinner" introduced all incoming students and parents to the VBRA leadership and Voelcker trustees, shared general information on the research strengths and infrastructure of the university, and included inspirational testimonials from VBRA Alumni about their VBRA experience. This event also featured an invited speaker (generally a UT Health San Antonio faculty member) who described his/her career achievements and provided advice and encouragement to the incoming Scholars.

Enrichment Activities. During Year 1, tours of local research institutes, healthcare organizations and biotechnology companies introduced Scholars to a range of environments and careers in the biomedical sciences. In addition, Scholars were invited to university lectures delivered by high-profile scientists, gala dinners to recognize scientific achievements across the city, and a VBRA holiday reception to reunite Scholars and Alumni.

Research and Mentoring. These were core components of the VBRA program, spanning all three years.

Research Mentor, Project Selection, and Research Activities. In Year 1, VBRA Scholars met with prospective Faculty Mentors and their research teams. Following a matching process to accommodate mutual interests, Scholars were paired with a mentor and worked with him/her to develop a feasible research project to be conducted over the following two years. Although the research projects were primarily carried out during the summer months, students were also encouraged to continue their research activities (including research-related events such as lab meetings, journal clubs, seminars, and workshops) throughout the school year.

The Scholars' projects were summarized in an abstract and presented as a poster at the *VBRA Graduation & Science Symposium* at the end of the first summer (see Table 1). This symposium was a large gathering attended by mentors, peers and parents at the end of each summer to: (a) offer a formal venue for Scholars to practice their presentation skills and discuss their research with other faculty and scientists, (b) provide lab coats and notebooks to all first-year Scholars to mark their formal entry into the lab and gift portfolios and pen sets to second-years Scholars to commemorate the start of the next chapter in their journey as they prepared for college, and (c) acknowledge the third-year Scholars who received a certificate of achievement for graduation from the Academy; these students contributed abstracts of their research projects for the graduation booklet, with several delivering oral presentations that highlighted their unique VBRA experiences.

Mentoring. Mentoring of VBRA Scholars was intentionally designed as a multi-tier experience and included peer, near-peer and training faculty. Peer and near-peer components engaged members from older cohorts and VBRA alumni as well as from the laboratories where the Scholars were placed, such as postdoctoral fellows, MD/PhD students, graduate, or undergraduate students (collectively called VBRA Junior Mentors). Junior Mentors trained VBRA Scholars in research techniques routinely used in the Faculty Mentor's laboratory and assisted them in abstract preparation and poster production. They also provided perspectives and guidance regarding their chosen career path. This approach provided valuable mentoring experience for Junior Mentors as they assumed day-to-day responsibilities in oversight of VBRA Scholars. In addition, weekly group sessions for first-year Scholars (*Peer-to-Peer Mentorship*) involved the participation of: (a) second-year VBRA Scholars, who provided guidance on navigating the expectations and responsibilities of being a Scholar, and (b) third-year Scholars, who presented "Scholar Insights" sessions, sharing best practices in the lab, refined techniques, and demonstrating leadership through role modeling. Mentorship and support from Program Administrators and VBRA Leadership were also available to all Scholars throughout the program.

The Outreach Office (ORSO) coordinated the onboarding process for Scholars and collaborated with several divisions, such as the Registrar, Environmental Health and Safety and the Police Department, to ensure all compliance documentation was completed, as the Scholars were minors working in a research environment. Lab-specific training was overseen by the Faculty Mentors. All Scholars completed institutional, state, and federal regulatory requirements for the responsible conduct of their specific research projects.

Mentor Recruitment and Regulatory Training. Faculty Mentors were recruited via an institution-wide email; an application form collected details of the potential mentor's area of research expertise and verified their commitment to Scholars for consecutive years. Faculty also had the opportunity to indicate their availability to provide lectures and participate in other VBRA educational activities. VBRA Junior Mentors were recruited by Faculty Mentors hosting VBRA Scholars, as well as by ORSO and OPA as needed.

As required by state law and the University of Texas System policies, institutional training focused on minors in the research workplace was provided to all mentors and personnel in the labs hosting VBRA Scholars. After successful completion of the online training, *Minors Conducting Research in the UTHSA Workplace: Child Protection Training,* individuals were registered with the Texas Department of State Health Services and certified to work with minors for up to two years.

Program Visibility and Dissemination. VBRA programmatic activities and outcomes were presented at regional and national conferences that included a focus on biomedical sciences pipeline programs (*e.g.*, *Understanding Interventions*, *Experimental Biology*, *Innovations in Health Science Education*, etc.). The VBRA also sponsored: (a) Scholar presentations at local conferences for high school teachers and at their own high schools as ambassadors of the VBRA, and (b) Scholar attendance at bioscience- and biotechnology-related events and symposia. These events were organized by local and national research organizations and offered opportunities for Scholars to interact and network with scientists and keynote speakers.

PROGRAM EVALUATION METHODS

The comprehensive assessment of VBRA programmatic components was continuous and included both internal and external evaluations.

Internal Evaluations. Anonymous surveys were routinely used throughout VBRA operations to assess the educational and networking activities of VBRA Scholars, Mentors, and Instructors. Results were utilized to inform ongoing programmatic adjustments. For example, pre/posttests (content-based questions designed by VBRA Instructors) enabled modification of didactic presentations. In addition, classroom assessment techniques, such as the *Minute Paper*, *Muddy Minute* and *Student Generated Questions* (Angelo & Cross, 1993)—which encouraged students to be responsible and accountable for the pace of their learning—provided feedback to Instructors regarding students' mastery of content knowledge. Further, skills assessment tests after each lab session evaluated Scholars' familiarity with specific lab techniques and manual skills.

The academic and research successes of individual VBRA Scholars were also monitored using a variety of specific outcome measures (e.g., science fair participation, VBRA research presentations and publications, final high school class rank and achievements/awards, collegiate accomplishments and majors, etc.). Details were derived from: (a) communications with Scholars (via email, social media, and the annual holiday celebrations), (b) the National Student Clearinghouse, and (c) external evaluators (see below).

Student-specific data regarding college/university enrollment and major were obtained from the National Student Clearinghouse (http://www.studentclearinghouse.org/). These data were used to compare details of VBRA Scholars with those of non-VBRA students. The latter were applicants to the VBRA program who were interviewed but not selected as Scholars. For purposes of comparison, non-VBRA students in a given year were derived from the same high school as VBRA Scholars in the corresponding year.

Programmatically, Scholars provided feedback regarding Faculty Instructors to improve teaching effectiveness via anonymous "Mentor Effectiveness" surveys. At the end of each summer, VBRA Scholars also provided an anonymous assessment of their respective Faculty Mentors regarding their availability, expertise, and integrity. The VBRA leadership used these assessments collectively to improve curriculum content and activities, identify mentors who might not be a good fit for the objectives of the program, and provide remediation to conflict, as needed.

External Evaluation. To assess the strengths and weaknesses of the VBRA program, a formal evaluation was conducted annually by an external consulting firm (DePass Academic Consulting). This evaluation included consideration of the VBRA curriculum, mentoring, research, and enrichment activities as well as non-cognitive measures related to Science Identity, Self-Efficacy and Sense of Belonging to the social and intellectual environments of the program and training environments. These measures reflected a Social Cognitive Career Theory framework, first described by Lent and his colleagues (Lent et al., 1994). Aspects of mentoring (technical, psychosocial, professional, and career) were also queried from the students' and training faculty perspectives. Information was collected through (a) anonymous surveys via SurveyMonkey prior to the annual site visit, and (b) focus group interviews, which included semi-structured meetings with individual groups—VBRA Leadership, Scholars, Faculty Mentors, Instructors, Junior Mentors, and Alumni. All results were considered in aggregate for a given group and summarized in comprehensive annual reports.

Scholar survey responses included declarative statements

Table 2. *VBRA program evaluation. Examples of domain-specific Scholar survey questions. Surveys were administered in an anonymous manner using Survey Monkey. For each item, responses were recorded using a Likert scale (1 =* strongly disagree*, 2 =* disagree*, 3 =* neutral*, 4 =* agree*, 5 =* strongly agree*).*

Domain	Survey Questions
Interest in Science	• I feel more sure that I want a career in science • I clarified what I want to do in a science career • VBRA stimulates my enthusiasm for science • VBRA makes science seem more interesting to me
Self-Efficacy	• I increased my confidence that I can handle science courses at the college level • I feel more self-assured as a student of science • I increased my confidence that I can succeed with science as a career
Acquisition of Scientific Knowledge and Skills	• I learned problem solving skills needed in science • I have a better grasp of how to write a research paper • I have a better understanding of what science is all about • I have "hands-on" experience that will help me in the future with science projects and activities • I learned science techniques I did not know before
Science Identity/ Peer Group Acceptance	• I realize it is OK to be smart and like science, even if some students in my high school don't think so • I had an opportunity to make friends with people who are a lot like me • I realized that some other people my age really respect and appreciate other students who are good at science • I see that many other students like science just like I do

where levels of agreement were rated for several domains (interest in science, self-efficacy, acquisition of scientific knowledge and skills, and peer group acceptance). Additionally, respondents had opportunities to further report their experiences through open-ended questions. Details for all domains are provided in Table 2 and responses were recorded using a Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree).

Study Approval. UT Health San Antonio's Institutional Review Board determined that this project did not require IRB approval (Protocol Number: HSC20180800N) as the research involved was not regulated as defined by DHHS regulations at 45 CFR 46 and FDA regulations at 21 CFR 56. All data were analyzed in aggregate, ensuring the anonymity and confidentiality of the participants. As such, the study fell under the category of exempt research as defined by institutional and federal guidelines, which specifically exclude certain educational settings from requiring IRB oversight when the risk to participants is minimal.

RESULTS

VBRA Scholars. From 2009 to 2022, the VBRA received a total of 1,244 applications from San Antonio-area high school students. Given significant programmatic changes in 2018 and 2019 (see Methods), the results presented below focus on VBRA features and outcomes prior to 2018.

Applicants, Interviews, and Scholars. Between 2009 and 2017, 486 individuals were chosen for in-person interviews from among 909 applications. Of these, 191 students were selected as VBRA Scholars (Figure 1). During this 9-year interval, an average of 101 complete applications were received annually and, excluding the inaugural year, approximately 60 individuals were interviewed. An average of 21 VBRA Scholars were selected each year. Thus, overall, 21% of applicants were admitted into the program. Throughout this 9-year period, 10 Scholars (5.2%) prematurely ended participation in VBRA for various personal/family reasons.

High Schools of VBRA Scholars. Scholars were students from 60 different San Antonio area high schools. This included a combination of 34 public, 12 private, and 14 charter high schools; the public high schools were operated by 11 independent school districts. The type of high school attended by individual VBRA Scholars varied annually, however, no specific trends were identified across all 9 years (Figure 2). During this interval, the average annual distribution of VBRA Scholars from public, private, and charter schools was 59.7 ± 4.3%, 32.8 ± 3.2%, and 7.6 ± 2.7%, respectively (mean ± SEM across 9 years). The percentage of VBRA Scholars from public schools was highest in all but one year (2010).

Diversity of VBRA Scholars. VBRA Scholars were diverse with respect to race and ethnicity throughout each year of the program (Figure 3). Students of Hispanic ethnicity were in the majority; i.e., 42.3 ± 3.5% across cohort years 2009-2017. The racial distribution of the remaining VBRA Scholars was White, non-Hispanic (32.0 ± 2.8%), Asian (17.4 ±3.3%), and Black or African American (8.3 ± 1.7%). The racial and ethnic distribution of VBRA Scholars reflected the demographics of the greater San Antonio area, except for the Asian group, whose percentage was higher in VBRA. Across all cohort years, more Scholars were female (59.3 ± 3.5%) than male (40.7 ± 3.5%).

Parental Education Level of VBRA Scholars. The highest level of parental education varied considerably among Scholars. In every cohort year, the distribution of the highest education level among both parents or the single custodian of each Scholar ranged from completion of high school to completion of an advanced degree (Figure 4); the parents of two Scholars did not have a high school diploma. Across all cohort years, 23.0 ± 3.2% of Scholars had parents whose highest level of education was a high school diploma with or without some college education, 19.6 ± 4.1% had a parent with an undergraduate degree, 23.6 ± 3.5% had a parent with a master's degree, and 33.9 ± 4.5% had a parent with an advanced, professional degree.

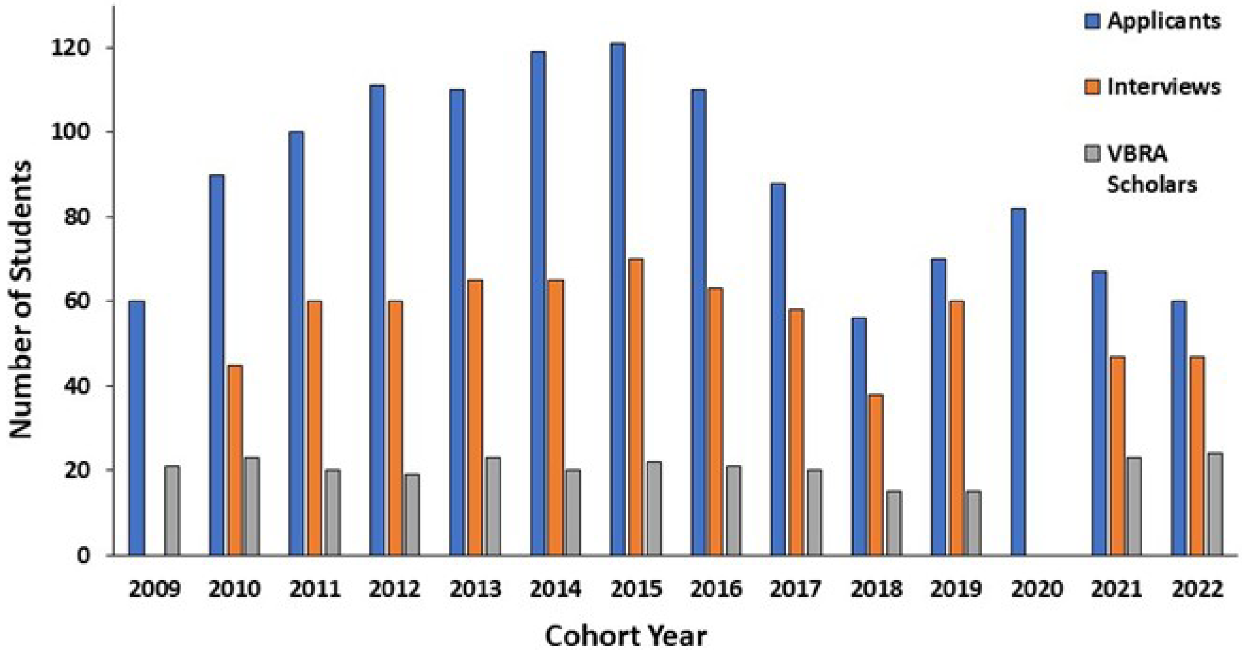

Figure 1. Applicants, interviews, and Scholars in the Voelcker Biomedical Research Academy (VBRA) (2009-2022). The total number of applicants progressively increased during the first seven years of the program. The number of VBRA Scholars was relatively constant; i.e., approximately 20 positions for each Cohort. Beginning in 2017, applications from a given high school were limited to three individuals each year, selected by a school-established process. Beginning in 2018, the program was modified from a 3-year to a 2-year research training plan. No Scholars were selected in 2020 due to the SARS-CoV-2 (COVID) pandemic. In 2021, the program returned to a 3-year period of research training.

VBRA Faculty Mentors. During 2009-2017, VBRA Scholars were mentored in the research laboratories/areas of faculty who were widely distributed across academic departments within the schools of dentistry, health professions, medicine, and nursing at UT Health San Antonio (Table 3). VBRA Faculty Mentors included both basic and clinical investigators. Most faculty held primary academic appointments within the school of medicine. Many VBRA Faculty Mentors were also affiliated with research institutes and centers on campus (e.g., Addiction Research, Treatment & Training Center of Excellence; Sam and Ann Barshop Institute for Longevity and Aging Studies; Center for Research to Advance Community Health; Glenn Biggs Institute for Alzheimer's & Neurodegenerative Diseases; Institute for Health Promotion Research; Institute for Integration of Medicine & Science; Mays Cancer Center; and Research Imaging Institute). These organized research units contributed to the robust research training environment for individual Scholars through regular seminar series, journal clubs, associated graduate research programs, and specialized equipment.

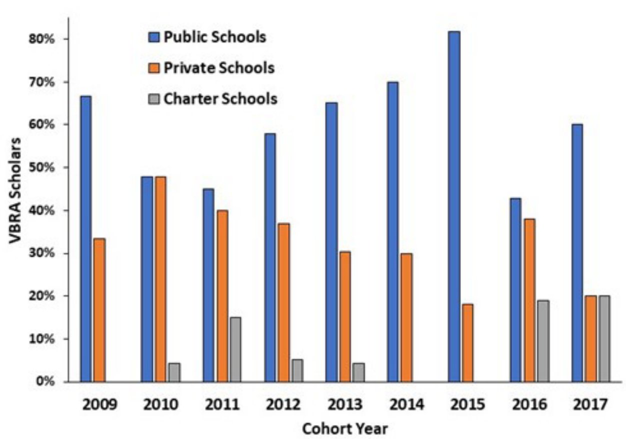

Figure 2. Types of high schools attended by VBRA Scholars (2009-2017). Throughout the program, VBRA Scholars were selected from among applicants who attended public, private, or charter schools in the San Antonio area. Data are presented as percentages for each individual year. Overall, the majority of VBRA Scholars (60%) attended public high schools.

VBRA Faculty Mentors varied in both academic rank (25 Professors, 23 Associate Professors, 33 Assistant Professors, and 3 Instructors) and advanced degrees (DO, MD, MD/PhD, RN/PhD, PhD, or PhD/MPH). The research areas encompassed by Faculty Mentors reflected the major research strengths of UT Health San Antonio; i.e., addiction, aging, behavioral sciences, cancer, diabetes, infectious disease, and neuroscience. Many individual Faculty Mentors engaged numerous VBRA Scholars over the course of nine years (Table 3). In part, this reflected the fact that the mentoring reputation of individual research faculty was often communicated among VBRA Scholars during routine programmatic activities that involved Scholars from across the entire 3-year spectrum (e.g., *Peer-to-Peer Mentorship* sessions).

Across all years, there were a total of 84 individual Faculty Mentors. VBRA Scholars (n=181) were evenly distributed among each faculty rank (Figure 5). The majority of VBRA

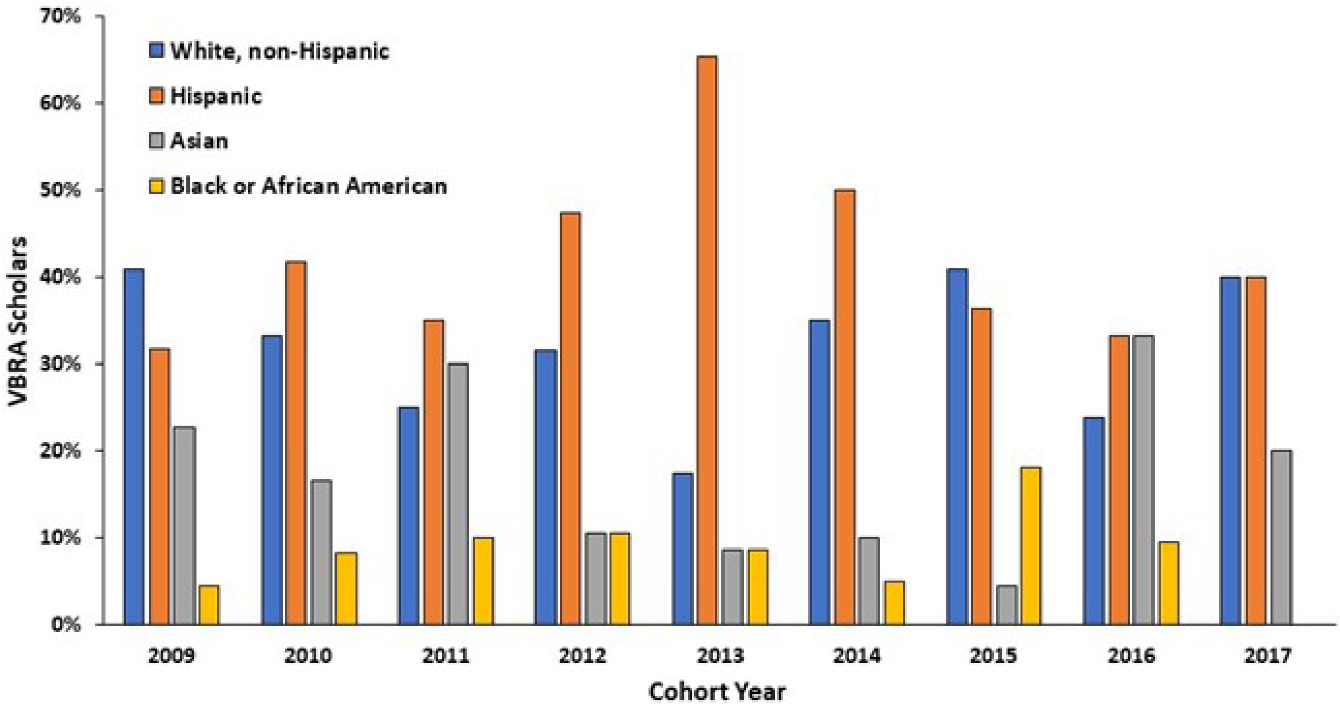

Figure 3. Race and ethnicity of VBRA Scholars (2009-2017). The self-reported racial and ethnicity status of VBRA Scholars (n = 189) was self-reported and reflected diversity among VBRA Cohorts. Data are presented as percentages for each individual year. Hispanic students constituted the highest demographic group within the VBRA Scholars (43%), a trend observed in most years of the program.

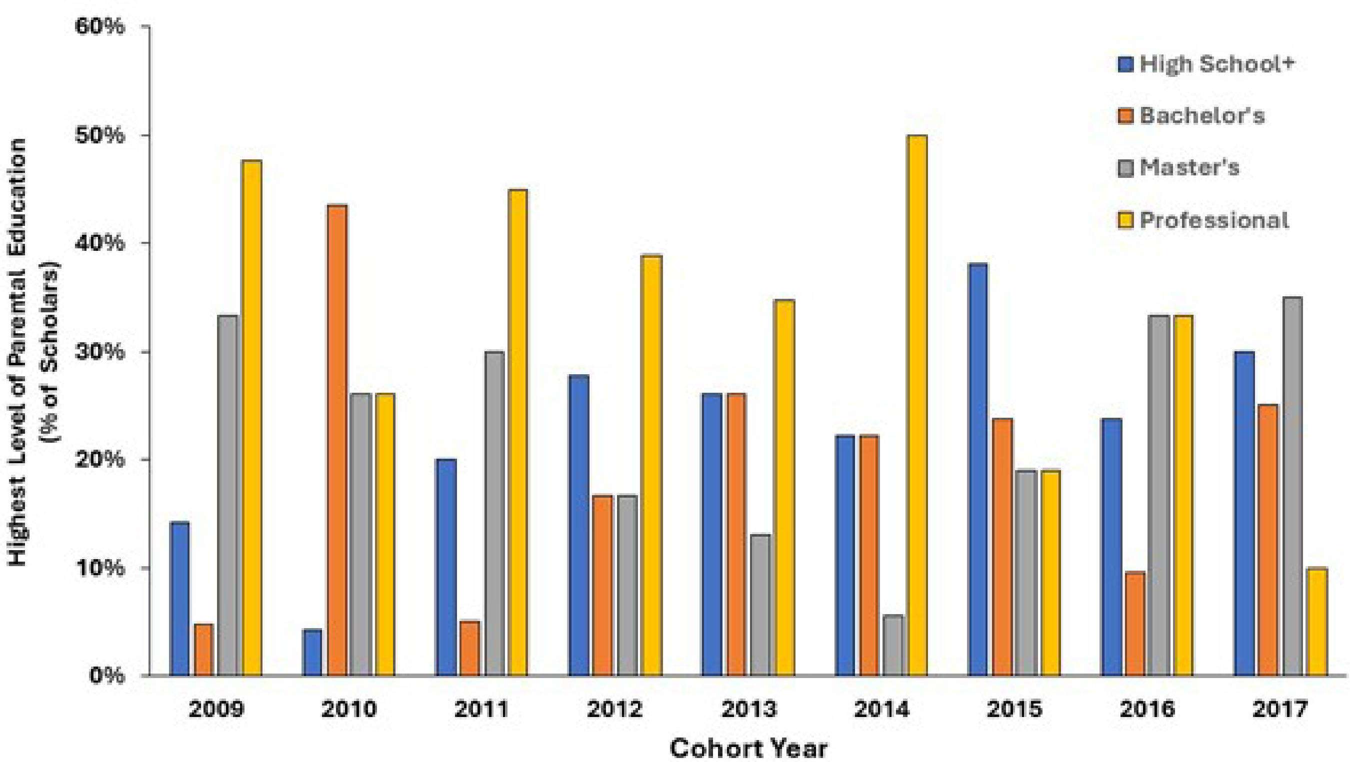

Figure 4. Parental education of VBRA Scholars (2009-2017). For a given Cohort Year, the percentage of VBRA Scholars was calculated in relation to the highest level of their parents' education. The highest level of parental education for VBRA Scholars was highly variable ranging from the completion of high school with or without some college (High School+) to the completion of an advanced postgraduate academic degree. The parents of the majority of VBRA Scholars had advanced degrees; i.e., Master's or higher.

Table 3. *Distribution of VBRA Scholars (2009-2017) among Schools/Departments/Mentors at The University of Texas Health San Antonio.*

School	Department / Division	VBRA Mentors (*n*)	VBRA Scholars (*n*)
Dentistry	Comprehensive Dentistry	2	3
	Oral & Maxillofacial Surgery	1	1
Health Professions	Clinical Laboratory Sciences	1	4
	Emergency Medical Services	2	5
Medicine	*Pre-clinical (basic science)*		
	Biochemistry & Structural Biology	3	11
	Cellular & Integrative Physiology	7	21
	Cell Systems & Anatomy	7	19
	Microbiology, Immunology & Molecular Genetics	8	11
	Molecular Medicine	2	3
	Pharmacology	10	18
	Clinical		
	Family and Community Medicine	1	1
	Medicine/Cardiology	3	3
	Medicine/Diabetes	1	2
	Medicine / Geriatrics	1	2
	Medicine / General Internal Medicine	1	11
	Medicine / Hematology and Oncology	1	1
	Medicine / Infectious Disease	1	10
	Medicine/Pulmonary	1	2
	Neurosurgery	2	4
	Obstetrics and Gynecology	5	11
	Pathology and Laboratory Medicine	2	5
	Pediatrics	5	7
	Psychiatry and Behavioral Medicine	8	14
	Radiology	3	4
	Surgery	1	4
	Urology	1	2
Nursing	Care Systems Management	2	4
	Family and Community Health	1	4

Scholars (*n*=72) joined the research programs of Assistant Professors, whose number (*n*=33) was the highest among all faculty ranks.

Scholar Outcomes. Several metrics were used to measure Scholar outcomes.

Research Publications. VBRA Scholars were introduced to the critical analysis of biomedical literature as well as to the importance of authorship and communicating research findings in the form of seminars, poster presentations, and/or peer-reviewed publications. Although not expected, several VBRA Scholars made significant contributions to the research programs of their Faculty Mentors and were recognized as co-authors in 16 full-length, peer-reviewed publications (two as first author). This was complemented by five first authored abstracts and corresponding poster presentations at diverse scientific meetings.

Table 4. *Distribution of VBRA Alumni enrollment in colleges and universities (Cohort Years 2009-2017). Enrollment for 177 VBRA Alumni was obtained from self-reports in combination with data from the National Student Clearinghouse. Four VBRA Alumni were lost to follow-up.*

Carnegie Classification	VBRA Alumni	
	Number	%
Associates Colleges	1	0.6%
Baccalaureate Colleges & Universities	18	10.2%
Master's Colleges & Universities – M1	5	2.8%
Doctoral Universities		
Very High Research Activity – R1	140	79.1%
High Research Activity – R2	11	6.2%
Doctoral/Professional Universities – D/PU	2	1.1%

Selection of University/College and Majors. VBRA Alumni attended colleges or universities throughout the United States. The majority (99%) matriculated into a 4-year undergraduate program upon completion of high school. Of note, 79.1% of VBRA Alumni (*n*=140) attended R1 research institutions (Table 4). Moreover, nearly 90% of VBRA graduates entered undergraduate studies with a declared major in STEM or related disciplines (Table 5).

Most VBRA Alumni (66%) attended colleges in Texas; the University of Texas at Austin, University of Texas at San Antonio, and Texas A&M University were the predominant in-state institutions (16.4%, 11.3%, and 10.2%, respectively). Twenty-eight VBRA Alumni (15.8%) attended colleges or universities in the San Antonio area (i.e., San Antonio College, St. Mary's University, Trinity University, University of the Incarnate Word, and University of Texas at San An-

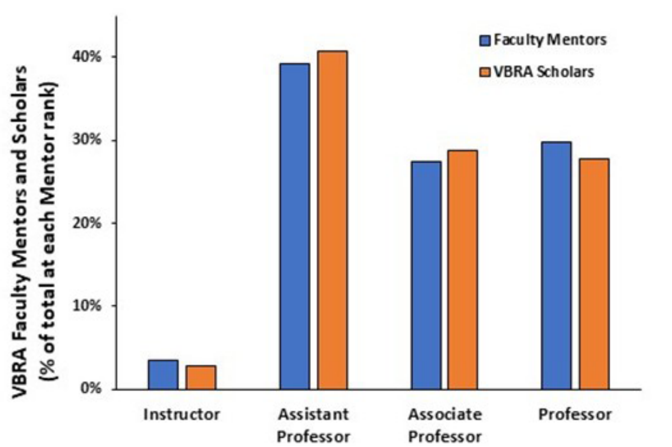

Figure 5. Distribution of VBRA Faculty Mentors and Scholars in relation to faculty rank (2009-2017). A higher percentage of VBRA Faculty Mentors were Assistant Professors with the other Mentors evenly distributed between Associate and Full Professors. Across all years, there were a total of 84 unique Faculty Mentors and 181 VBRA Scholars. Data are presented as the percent of the total VBRA Scholars with mentors at each mentor rank.

Table 5. *College or university major of VBRA Alumni (Cohort Years 2009-2017). Majors for 177 VBRA Alumni was obtained from self-reports in combination with data from the National Student Clearinghouse. Four VBRA Alumni were lost to follow-up.*

College Major	n	%
Biology and Biological Sciences	94	53.1%
Chemistry	13	7.3%
Engineering	23	13.0%
Math and Computer Science	8	4.5%
Other (STEM)	18	10.2%
Other (non-STEM)	13	7.3%
Undeclared	8	4.5%

tonio). Among these Alumni attending local colleges, 75% were Hispanic and 57% had parents whose highest education was a high school diploma with or without some college. Approximately one-third of VBRA Alumni (33.9%) pursued undergraduate studies in academic institutions outside of Texas, including 15 who attended Ivy League schools.

Among the VBRA Scholars (*n*=72) who were mentored by Assistant Professors, 68% subsequently matriculated into a R1 institution for undergraduate studies (Figure 6A). This was contrasted with a higher percentage of Scholars attending similar institutions who were mentored by Associate Professors or Professors (i.e., 84% or 88%, respectively) (Figure 6A). Moreover, Scholars mentored by Assistant Professors mainly selected in-state R1 institutions, whereas a higher percentage of those training with senior faculty matriculated into out of state institutions (Figure 6B).

To assess whether participation in VBRA influenced university/college selection and major, we used data obtained from the National Student Clearinghouse (NSC) to compare the outcomes of VBRA Scholars from 2013-2016 (*n*=79) to those of unsuccessful VBRA applicants (*n*=142) who attended the same high schools each year (collectively described as non-VBRA students). Three VBRA Alumni (3.8 ± 1.3%) and 48 non-VBRA students (30.3 ± 6.5%) lacked information in the NSC database. For the 76 VBRA Scholars and 94 non-VBRA students included in the NSC database, most of both groups attended universities and colleges in Texas (Figure 7A). Nevertheless, more non-VBRA students (82.6 ± 2.5%) remained in Texas as compared to VBRA Scholars (68.5 ± 3.9%). Most striking was the difference between these two groups relative to attendance at 2-year colleges (i.e., lower among VBRA Scholars, Figure 7B), as well as at out-of-state universities (i.e., greater among VBRA Scholars, Figure 7C). Slightly more VBRA Scholars (89.1 ± 4.0%) majored in STEM or a related discipline as compared to non-VBRA students (82.9 ± 4.0%) (Figure 7D). Although Scholars had higher four-year college attendance and STEM major rates than non-VBRA students, this difference may not be explained by selection bias, as all applicants (including those who were not selected) were high-performing students.

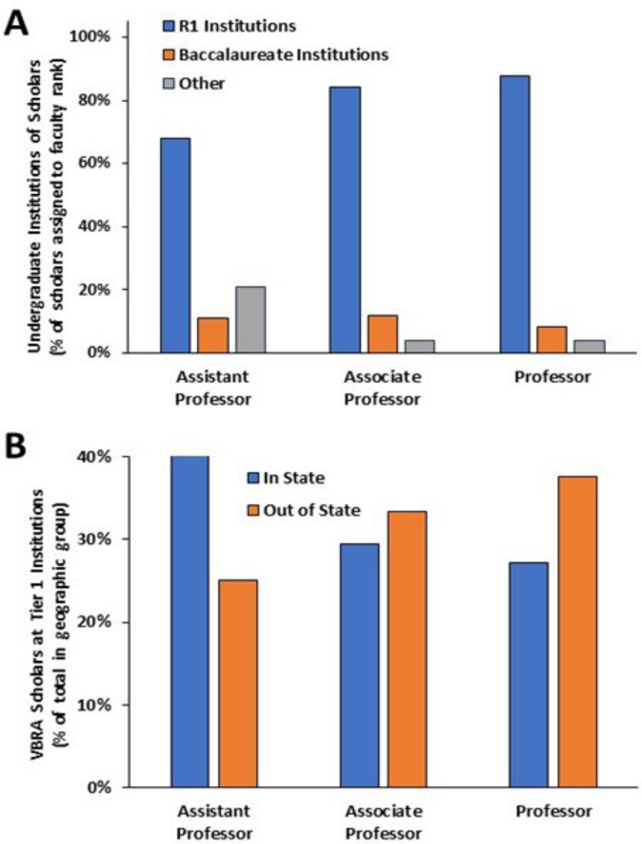

Figure 6. Distribution of colleges attended by VBRA Scholars in relation to Faculty Mentor rank. **A.** Scholars at R1, Baccalaureate, and other institutions; other institutions include R2 (Doctoral Universities–high research activity), D/PU (Doctoral/Professional Universities), M1 (Master's Colleges and Universities–larger programs), and A (Associate's Colleges). Among all Scholars (*n* = 177), a greater percentage who were mentored by Associate Professors or Professors matriculated into R1 institutions as compared to those mentored by Assistant Professors. Results are expressed as the percent of total assigned Scholars at each mentor rank. **B**. The majority of VBRA Scholars attended R1 institutions (Doctoral Universities–very high research activity) for undergraduate studies. Assistant Professors mentored more Scholars who matriculated at in-state R1 institutions and less who matriculated at out-of-state R1 institutions. Results are expressed as the percent of all Scholars who attended R1 institutions (*n* = 140).

Nevertheless, these outcomes cannot be attributed solely to participation in the VBRA program.

After the completion of undergraduate studies, self-reported data from 135 Scholars indicated that 72% (*n*=96) either entered advanced STEM studies (e.g., medical school) or began a STEM-related career (e.g., engineering) (Table 6).

Programmatic Evaluation. External evaluation of VBRA activities led to straightforward programmatic adjustments. For example, *Throw-back Tuesdays*, a weekly lunchtime meeting of individual Scholar cohorts, was readily implemented after comments revealed the perceived importance of group meetings beyond the first year in the program.

As revealed by structured questions, external evaluations

Table 6. *VBRA Scholar activities after completion of undergraduate studies (Cohort Years 2009-2017). Staus is based on self-reported data from 135 of 163 VBRA Alumni. Examples of advanced STEM studies included medical, dental, nursing, graduate, pharmacy, or veterinary schools; examples of advanced non-STEM studies included graduate or law schools; examples of STEM-related career employment included laboratory assistants, science and math teachers, engineers; examples of non-STEM-related career employment included business administrators, financial analysts, journalists, lawyers.*

Status	n	%
Enrolled in or completed advanced STEM studies	50	37.0%
Enrolled in or completed advanced non-STEM studies	9	6.7%
STEM-related career employment	47	34.8%
Non-STEM-related career employment	29	21.5%

also indicated that VBRA Scholars were actively engaged throughout all three years (Table 7). Of note, science identity, a self-assessed sense of belonging within the scientific community, was strongly emphasized. High ratings in structured questions were paralleled by VBRA Scholars' written comments. A selection of representative Scholars' responses is summarized in Table 8. Further, those comments mirrored the volunteered statements provided in annual communications between VBRA Alumni and the program leadership (Table 9). Indeed, Alumni expressed continued appreciation for the VBRA experience for many years beyond their active participation in the program.

DISCUSSION

Scientific innovation and discovery provide the foundation for biomedical breakthroughs that advance contemporary health care. Most well-trained investigators conduct research with resources largely provided by public and private funding agencies. These same agencies support other members of the biomedical workforce through research education and training programs that target undergraduate and graduate students and postdoctoral research fellows. More recently, funding opportunities have extended to include high school students. Collectively, the STEM workforce pipeline is crucial for continued excellence in the biomedical sciences.

The Voelcker Biomedical Research Academy (VBRA) was established as a pipeline program for motivated and meritorious San Antonio, Texas, high school students to participate in multi-year research activities under the mentorship of an established scientist. At UT Health San Antonio, VBRA aimed to enhance student awareness of and enthusiasm for STEM professional careers through a combination of hands-on research activities, mentoring, networking, and college/career guidance. Overall, VBRA effectively achieved its programmatic objectives and facilitated the transition of high school students into STEM-related advanced education and careers.

Historically, most summer research programs for high school students in the U.S. have emphasized the workforce development of individuals who are underrepresented in science. Indeed, this has been a major focus of training grants funded by the National Institutes of Health (NIH) and the National Science Foundation (NSF) that support summer research and related educational experiences for undergraduate and high school students. Although VBRA was not designed to specifically address diversity in the biomedical

Table 7. *Survey outcomes of VBRA Scholars. Data are from an anonymous survey conducted at the end of summer by an external evaluator. Using a Likert scale (1* = strongly disagree*, 2* = disagree*, 3* = neutral*, 4* = agree*, 5* = strongly agree*), results are expressed as the average for the group.*

Domain	3rd Year Class of 2014 (*n* = 12)	2nd Year Class of 2015 (*n* = 14)	1st Year Class of 2016 (*n* = 18)
Interest in Science			
Increased interest for a career in science	4.0	4.8	4.7
Clarified what I want to do in a science career	4.5	4.3	4.1
Self-Efficacy			
Increased confidence that I can handle science courses at the college level	4.5	4.9	4.7
More self-assured as a student of science	4.6	4.8	4.7
Increased confidence that I can succeed with science as a career	4.5	4.7	4.7
Acquisition of Scientific Knowledge and Skills			
Learned problem solving skills needed in science	4.7	4.8	4.7
Better grasp of how to write a research paper	4.5	3.9	4.4
"Hands-on" experience that will help in the future with science projects and activities	4.9	4.9	4.9
Enhanced my knowledge of science	5.0	4.8	4.9
Science Identity/Peer Group Acceptance			
Opportunity to make friends with people who are a lot like me	4.7	4.8	4.6
It's okay to be smart and like science, even if some students in my high school don't think so	4.8	4.8	4.2

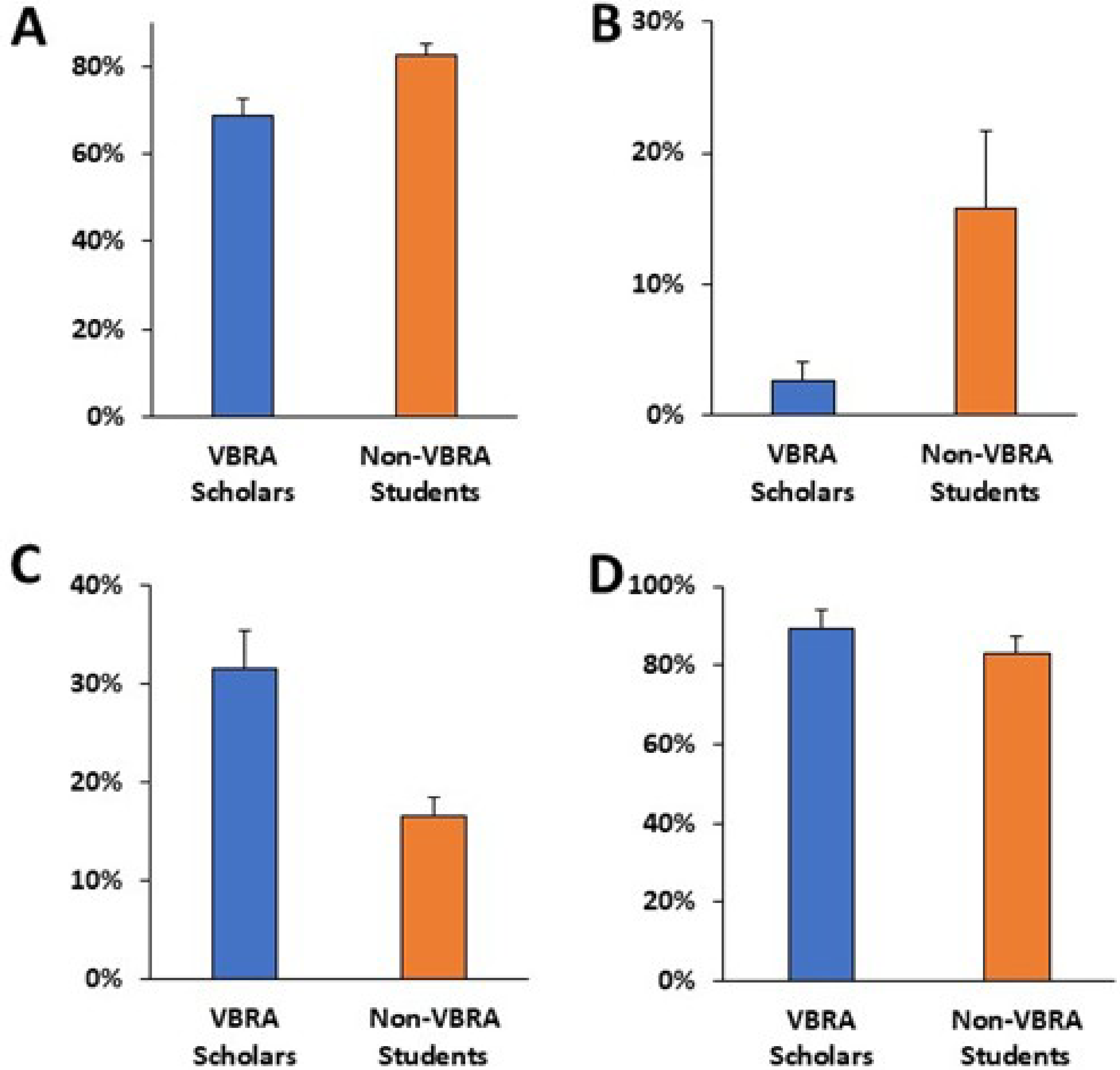

Figure 7. Comparison of college selections of VBRA Scholars and non-VBRA students. College/university enrollment and major were obtained from the National Student Clearinghouse and used to compare VBRA Scholars (n = 76) with non-VBRA students (n = 94) who were applicants not selected for the VBRA program. **A**. In-state (Texas) college attendance. **B**. 2-year college attendance. **C**. Out-of-state college attendance. **D**. College STEM majors. Results are expressed as the percent of group total and represent the mean + SEM.

workforce, the majority of VBRA Scholars were Hispanic, which reflected San Antonio demographics. A strength of VBRA was the large geographical distribution of Scholars' high schools which enabled the integration of students with diverse experiences, socio-economic status, ethnicity, and perspective.

The format and duration of STEM-related research education and training programs for U.S. high school students have ranged considerably, including virtual classes, summer classroom/experiential activities of one to eight weeks, a single summer research internship, and an extended (multiyear) research internship (*e.g.*, Rohrbaugh & Corces, 2011; Rosenbaum et al., 2007; Winkleby, 2007). These research-related programs differ greatly in required resources, and each has distinct strengths and weaknesses. For example, an online research education course using existing telecommunication networks potentially allows larger groups of students to attend without travel/distance limitations; while this approach may be the most financially feasible, hands-on laboratory experiences are lacking. Conversely, the involvement of established investigators who are conducting research in well-resourced and staffed facilities requires a much higher level of funding, programmatic organization, and institutional commitment. Since 2009, VBRA has enabled a robust and sustained research training program for high school students by leveraging UT Health San Antonio infrastructure and local private funding. Although the comparative effectiveness and long-term value of the various educational programs to

Table 8. *Scholar comments regarding VBRA. These open-ended comments in response to the prompt, "*How do you think you have benefitted from participation in the program this year?*" were collected in an anonymous survey completed at the end of the summer. Y1, Y2, and Y3 = Individual years of the 3-year program (Year 1, Year 2, and Year 3, respectively).*

Importance, relevance, and benefits of the program
Program has opened my eyes to the diversity of science (Y1 Scholar)
Gained a lot of experience that I would never have been able to get elsewhere (Y1 Scholar)
Learned some very important things such as professionalism through the experiences throughout the program (Y1 Scholar)
Learned how to think for myself, manage time efficiently, and analyze solutions and solve problems better (Y2 Scholar)
Strengthening my expertise of biology and problem solving (Y2 Scholar)
A valuable experience that opened my eyes to what it is like to work alongside professionals in a scientific laboratory (Y2 Scholar)
New communication strategies, cross-cultural connections, increased confidence, and a wealth of new knowledge and skills (Y3 Scholar)
STEM education and careers
Gained a strong connection with peers and mentors (Y1 Scholar)
Better understanding of what a career in the medical field looks like (Y1 Scholar)
More confident in my choice to pursue research as a career (Y2 Scholar)
Learned valuable skills that will benefit my career in biomedical research lab (Y2 Scholar)
Better understanding of science, research, and what a work environment is like (Y3 Scholar)
Self-efficacy
Build presentation skills I thought were unobtainable (Y1 Scholar)
Learned how to multitask more efficiently (Y2 Scholar)
Gained a greater sense of independence (Y2 Scholar)
Confidence has improved immensely, learned to make small talk, and run experiments all by myself (Y3 Scholar)
Further developing my independence, presenting to the younger scholars, discussing project with my mentors, answering younger scholars' questions and concerns (Y3 Scholar)

introduce research at the high school level remain to be established, VBRA outcomes align with those of others (*c.f.*, Lopatto, 2007; Rohrbaugh & Corces, 2011) and indicate that active participation in research activities provides a pathway for the recruitment of students into STEM-related careers.

Distinguishing features of VBRA included a robust introduction to research fundamentals in the first summer followed by hands-on research for the subsequent two years. Throughout this 3-year interval, Scholars returned to the university campus during the academic year to attend lectures and professional development events. The VBRA curriculum not only included essential concepts of contemporary biomedical sciences, but also demonstrated the complexity of the research ecosystem; *i.e.*, team science, research funding, scientific integrity, and rigor and reproducibility in science. This approach emphasized the acquisition of scientific knowledge, critical and creative thinking, and problem solving, as well as the development of communication, leadership, and social skills. By moving students away from traditional high school science experiments and introducing them to a more rigorous and inquiry-based approach in a laboratory setting, students gained a better idea of what "real science" entails. Scholars did not merely shadow ongoing experiments in the lab. Rather, they identified, under the guidance of mentors, relevant research questions and developed a feasible research project. Scholars were encouraged to present their findings at lab meetings as well as in their high schools. Of note, several VBRA Scholars co-authored peer-reviewed papers and scientific abstracts and formally presented research findings at local and national research conferences. Overall, Scholar achievements in science and academia contributed to their sense of "ownership" of the discoveries resulting from their respective projects. Thus, the VBRA training experience encouraged confidence building and intentionality, which may have influenced college and career choices.

VBRA developed Scholars' skills and knowledge together with first-hand research experiences to facilitate a sense of belonging in science and thus a science identity (*e.g.*, self-efficacy, self-perception, or expectations) that was further enhanced by established relationships with peers and mentors. This aligns well with the recognized importance of science identity, especially among historically marginalized populations (*c.f.*, Curvey-Johnson et al., 2023; Vincent-Ruz & Schunn, 2018). Although VBRA was not designed to rigorously assess Scholars' science identity, their college and career outcomes are consistent with the likelihood that participation in VBRA positively impacted their choice to pursue long-term involvement in STEM.

The programmatic efforts of VBRA cultivated experiential learning. The merit of this approach was realized as Scholars continued their interests in STEM beyond their participation in the program. Comparable outcomes have been observed among students entering other pipeline programs with active research engagement (*c.f.*, Eeds et al., 2014; Hurtado et al., 2007; Rohrbaugh & Corces, 2011; Salto et al., 2014; Schultz et al., 2011).

Table 9. *Examples of voluntary comments VBRA Alumni provided in response to the program's annual communications with them.*

I'm doing well in my first semester of grad school at UT. I'm pursuing the microbiology PhD track. The skills I first learned through Voelcker are still serving me well! (2009 Cohort)
I am currently finishing up my first semester of medical school at Baylor College of Medicine in Houston. Looking back, participating in the Voelcker program was one of the best decisions I made, as it set me up for future successes. (2009 Cohort)
Being a part of the Voelcker Academy was a huge part of my journey to becoming a physician. I had incredible exposure to basic science research and access to incredible scientists and physician-scientists as mentors. The educational workshops we had throughout the three years covered a breadth of science and medicine topics and were extremely helpful. I took all of the skills I learned and applied them throughout the years as I continued to conduct research in college, medical school, and now in residency. (2010 Cohort)
I've been making good use of the presentation and writing skills I learned during my time in Voelcker. I have been able to present my research at several conferences and poster sessions for aerospace engineering and physics. The first satellite I've helped build is scheduled to launch in January. I want you to know that you and the rest of the Voelcker family sure helped me get a good start in science. (2010 Cohort)
Voelcker helped open all the doors that led me to where I am today. I grew and learned so much through the program. I know that the letters of recommendation written by my mentor led to my acceptance into Brown and the Gates scholarship. I was a poor kid from a rough side of San Antonio. I never thought I could get into an Ivy League school, graduate with honors, or get a job where I love every single moment of work. Voelcker showed me that those possibilities existed. Many generations of my family have suffered and worked hard to make the next generation better than the last. All I needed was a chance. Voelcker didn't just impact my career trajectory. It impacted my life trajectory. (2012 Cohort)
The Voelcker Academy supplied me with the skills to not just learn but to also participate in the real world. I learned strong communication skills, critical thinking skills and the ability to understand and apply research. (2014 Cohort)
Voelcker influenced my desire to have a career in medicine and support it with clinical research; it also influenced my interest in studying the human brain. (2016 Cohort)

Mentorship is a key factor in the development, success, and career choice of STEM trainees (Estrada et al., 2018; Hernandez et al., 2017). Consequently, VBRA was designed to offer a multi-tiered mentoring experience by engaging not only faculty, but also junior mentors (i.e., postdoctoral research fellows, graduate or undergraduate students, advanced VBRA Scholars, and graduate students enrolled in dual degree programs). Somewhat surprisingly, our data indicate that the rank of the VBRA faculty mentor may have impacted the college destinations of Scholars. Indeed, a smaller percentage of Scholars matriculated at R1 institutions if trained by early career faculty (Instructors and Assistant Professors) as compared to Scholars trained by Associate Professors or Professors. Most Scholars mentored by early career VBRA faculty remained at in-state institutions. As we lacked robust data to conduct an in-depth analysis of Scholars' college selection in relation to their mentors' rank by discipline, further research is necessary to identify what specific factors (e.g., mentoring experience, relevance of the research projects, exposure to a more established research environment, Scholar-faculty matching process, Scholar-dependent circumstances, etc.) might have contributed to these outcomes.

The college outcomes of VBRA Scholars suggest that the VBRA experience sustained Scholars' interests in STEM and influenced their college selection and pursuit of careers in biomedical fields. As importantly, the sustained interest of VBRA Alumni in STEM disciplines is much higher than the national average reported for college students regardless of their ethnicity or racial background (de Brey et al., 2018). Ninety-nine percent of Scholars enrolled in a 4-year undergraduate program, and most (79%) matriculated at R1 institutions. Over 70% of Scholars started and/or completed advanced STEM education programs. Of particular note, analysis of college attendance by VBRA Scholars versus their respective peers who were not selected for participation in VBRA indicated that a large percentage of the latter (30%) did not attend college. Given the above, the college and career outcomes of VBRA Scholars indicate a positive impact of the 3-year research training experience on the high school STEM pipeline.

Based on self-reported data, approximately 15% of VBRA Scholars were first-generation college students; the majority subsequently attended colleges and universities. These findings underscore the fundamental importance of early exposure to structured and rigorous science experiences to engage students in STEM disciplines and improve their preparation and competitiveness for related career choices. Additional studies are required to more closely define the impact of the VBRA program on first-generation college students.

We believe that the VBRA program's approach—combining extended research training with community building and the cultivation of a strong science identity for high-school students—can be adapted to other research institutions with adequate resources. Key efforts should focus on delivering sustained, high-quality peer mentoring, multi-year research training, networking opportunities, and professional development.

Despite VBRA successes, general considerations that may limit the implementation at other institutions of this type of multi-year research education and training program for high school students include: (a) limited funding to support these efforts, (b) unwillingness of some faculty and staff to oversee the programmatic aspects due to inadequate incentives, (c) requirement for institutional commitment to provide space, in-kind support, and community outreach, and (d) low numbers of science champions for high school students pursuing research-focused endeavors at both the high school and university levels. Addressing these challenges could allow support and expansion of multi-year pipeline programs. From our nine years of experience with VBRA, we have learned that proactive strategies are essential for recruiting and retaining mentors in a long-running program. For example, engaging institutional leaders as champions, publicly recognizing faculty mentors' contributions, and offering a modest research stipend for mentors proved effective in encouraging faculty participation. These efforts allowed us to maintain a strong pool of mentors each year, despite the significant time commitment required. In parallel, it will be important to assess the impact and efficacy of this type of multi-year research education and training program in other geographical regions and populations.

In conclusion, VBRA established a robust pipeline of students who excelled academically, were committed to community and service, and went on to pursue advanced bioscience education and/or STEM-related careers.

AUTHOR INFORMATION

Corresponding Author

Andrea Giuffrida, PhD, MBA, Senior Vice President for Research & Biotechnology and Professor of Pharmacology, Department of Medical Sciences, Western University of Health Sciences. 309 E. Second Street, Pomona, CA, 91766.

Author Contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript.

Author Notes

The activities described in this article were conducted at the University of Texas Health San Antonio (UT Health San Antonio). This institution has since merged with another university, which is now known as the University of Texas at San Antonio (UTSA).

ACKNOWLEDGMENTS

We acknowledge all VBRA Faculty, Junior Mentors and the Office of Recruitment and Science Outreach (ORSO) team for their invaluable contributions. We are also grateful to prior advisors who historically contributed to VBRA ideation and implementation.

FUNDING SOURCES

The Voelcker Biomedical Research Academy (VBRA) was primarily supported by the Max and Minnie Tomerlin Voelcker Fund, as well as in-kind resources from UT Health San Antonio.

ABBREVIATIONS

COVID: SARS-CoV-2; NIH: National Institutes of Health; NSF: National Science Foundation; NSC: National Student Clearinghouse; OPA: Office of Postdoctoral Affairs; ORSO: Office of Recruitment and Science Outreach; SCCT: Social Cognitive Career Theory; STEM: Science, Technology, Engineering, and Math; VBRA: Voelcker Biomedical Research Academy

REFERENCES

Ahmad, Z., Ammar, M., & Al-Thani, N. J. (2021). Pedagogical models to implement effective STEM research experience programs in high school students. *Education Sciences, 11*(11), 743. https://doi.org/10.3390/educsci11110743

Angelo, T. A. & Cross, K. P. (1993). *Classroom assessment techniques: A handbook for college teachers*. Jossey-Bass.

Cantor, J. C., Bergeisen, L., & Baker, L. C. (1998). Effect of an intensive educational program for minority college students and recent graduates on the probability of acceptance to medical school. *Journal of the American Medical Association, 280*, 772-776. https://doi.org/10.1001/jama.280.9.772

Chemers, M. M., Zurbriggen, E. L., Syed, M., Goza, B.K., & Bearman, S. (2011). The role of efficacy and identity in science career commitment among underrepresented minority students. *Journal of Social Issues, 67*(3), 469–491. https://doi.org/10.1111/j.1540-4560.2011.01710.x

Covey, S. R. (2013). *The 7 habits of highly effective teens: Powerful lessons in personal change*. Simon & Schuster.

Curvey-Johnson, R., Gallegos, N., Hampton, H., Caffey, D., Bailey, K., Vigil, E., Culbreath-Byrd, T., Jenkins, D., & Freeman, A. (2023). Cultivating STEM/Health identities and talent in historically marginalized populations through equity-focused place-based learning: the Rush Education and Career Hub (REACH) model. *Journal of STEM Outreach, 6*(2), 1-18. https://doi.org/10.15695/jstem/v6i2.04

Dabney, K. P., Chakraverty, D., & Tai, R. H. (2013). The association of family influence and initial interest in science. *Science Education, 97*(3), 395-409. https://doi.org/10.1002/sce.21060

de Brey, C., Musu, L., McFarland, J., Wilkinson-Flicker, S., Diliberti, M., Zhang, A., Branstetter, C., & Wang, X. (2019). *Status and trends in the education of racial and ethnic groups* (NCES 2019-038). U.S. Department of Education, National Center for Education Statistics. https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2019038

Eeds, A., Vanags, C., Creamer, J., Loveless, M., Dixon, A., Sperling, H., McCombs, G., Robinson, D., & Shepherd, V. L. (2014). The School for Science and Math at Vanderbilt: An innovative research-based program for high school students. *CBE—Life Sciences Education, 13*(2), 297–310. https://doi.org/10.1187/cbe.13-05-0103

Estrada M., Hernandez P. R., & Schultz P.W. (2018). A longitudinal study of how quality mentorship and research experience integrate underrepresented minorities into STEM careers. *CBE—Life Sciences Education. 17*(ar9), 1-13. https://doi.org/10.1187/cbe.17-04-0066

Fouad, N. A., & Santana, M. C. (2017). SCCT and underrepresented populations in STEM fields: Moving the needle. *Journal of Career Assessment, 25*(1), 24-39. https://doi.org/10.1177/1069072716658324

Funk, C., & Parker, K. (2018). Women and men in STEM often at odds over workplace equity. Pew Research Center. https://www.pewresearch.org/wp-content/uploads/sites/20/2018/01/PS_2018.01.09_STEM_FINAL.pdf

Hernandez, P. R., Estrada, M., Woodcock, A., & Schultz, P. W. (2017). Protégé perceptions of high mentorship quality depend on shared values more than on demographic match. *Journal of Experimental Education. 85*(3), 450-468. https://doi.org/10.1080/00220973.2016.1246405

Hurtado, S., Cabrera, N. L., Lin, M. H., Arellano, L., & Espinosa, L. L. (2007). Diversifying science: Underrepresented student experiences in structured research programs. *Research in Higher Education, 50*(2), 189-214. 10.1007/s11162-008-9114-7

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behavior, 45*(1), 79-122. https://doi.org/10.1006/jvbe.1994.1027

Lopatto, D. (2007). Undergraduate research experiences support science career decisions and active learning. *CBE—Life Sciences Education, 6*(4), 297-306. https://doi.org/10.1187/cbe.07-06-0039

National Science Board, National Science Foundation (2022). *Science and engineering indicators 2022: The state of U.S. science and engineering (NSB-2022-1).* https://ncses.nsf.gov/pubs/nsb20221

National Science Foundation, National Center for Science and Engineering Statistics (2023). *Diversity and STEM: Women, minorities, and persons with disabilities 2023 (Special report NSF 23-315)*. https://www.nsf.gov/reports/statistics/diversity-stem-women-minorities-persons-disabilities-2023

Noonan, R. (2017). *STEM jobs: 2017 update (ESA Issue brief # 02-17).* US Department of Commerce. https://eric.ed.gov/?id=ED594354

Rohrbaugh, M. C., & Corces, V. G. (2011). Opening pathways for underrepresented high school students to biomedical research careers: The Emory University RISE program. *Genetics, 189*(4), 1135-1143. https://doi.org/10.1534/genetics.111.132126

Rosenbaum, J. T., Martin, T. M., Farris, K. H., Rosenbaum, R. B., & Neuwelt, E. A. (2007). Can medical schools teach high school students to be scientists? *The FASEB Journal, 21*(9), 1954-1957. https://doi.org/10.1096/fj.06-7845lsf

Sahin, A., Ekmekci, A., & Waxman, H. C. (2017). Collective effects of individual, behavioral, and contextual factors on high school students' future STEM career plans. *International Journal of Science and Mathematics Education, 15*(85), 1-21. https://doi.org/10.1007/s10763-017-9847-x

Salto, L. M., Riggs, M. L., De Leon, D. D., Casiano, C. A., & De Leon, M. (2014). Underrepresented minority high school and college students report STEM-pipeline sustaining gains after participating in the Loma Linda University summer health disparities research program. *PLoS ONE, 9*(9), e108497. https://doi.org/10.1371/journal.pone.0108497

San Antonio Chamber of Commerce (2022). *Annual report.* https://www.sachamber.org/resources/annual-report/

Schultz, P. W., Hernandez, P. R., Woodcock, A., Estrada, M., Chance, R. C., Aguilar, M., & Serpe, R. T. (2011). Patching the pipeline: Reducing educational disparities in the sciences through minority training programs. *Educational Evaluation and Policy Analysis, 33*(1), 95-114. https://doi.org/10.3102/0162373710392371

Vincent-Ruz, P., & Schunn, C. D. (2018). The nature of science identity and its role as the driver of student choices. *International Journal of STEM Education, 5*, 1-12. https://doi.org/10.1186/s40594-018-0140-5

Winkleby, M. A. (2007). The Stanford Medical Youth Science Program: 18 years of a biomedical program for low income high school students. *Academic Medicine, 82*(2), 139-145. https://doi.org/10.1097/ACM.0b013e31802d8de6