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Collaborative STEM Research Training Model to Engage Underrepresented High School Students to Strengthen and Diversify the Biomedical Workforce

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ABSTRACT: Programmatic interventions that expose students from underrepresented backgrounds to biomedical research increases enrollment and persistence in STEM college degrees and have the potential to strengthen the research workforce. Here, we report pre- and post-participation survey data from 706 students (92% in high school) identifying from underrepresented groups in science. Most (76%) did not have prior research exposure or direct connection to biomedical research. They participated at one of eight US internship sites that collaborated to provide a common training curriculum (hands-on research, supportive mentoring, enrichment activities, and student stipends), with unique research experiences. Students reported a high satisfaction with programming (95%) and gains in each of the 14 scientific skills assessed. The most significant gains occurred in students' attitudes toward their ability to analyze data and understand the research process. Importantly, 78% of the students reported the program positively influenced their interest in future research. These findings provide further support that engagement of underrepresented students in research during formative high school years is an effective intervention. The collaborative research training model allowed participating sites to leverage their own local expertise while engaging in adaptive programming that suited both the institution and the needs of its area high school students.

INTRODUCTION

A 2011 National Academies Report highlighted the benefits of applying cohort-based mentored research experiences for early engagement of students in science and technology disciplines (NASEM, 2011). In response, the Doris Duke Foundation (DDF), a longstanding supporter of clinical research, launched a national effort to meet this opportunity and cultivate interest in biomedical research careers among high school (HS) students through biomedical research experiences supported by the Clinical Research Continuum (CRC) program. The CRC program uses an apprenticeship-style hands-on approach to engaging in research as a strategy to attracting and retaining HS students in STEM education and career paths.

Ultimately, this national effort aims to build evidence for approaches that, at scale, have the potential to ameliorate the disproportionate makeup of the biomedical research field compared to national demographics (STEMM Opportunity Alliance, n.d.). U.S. census data from 2023 show that 13.6% of the American population is Black or African American and 19.1% is Latino/a or Hispanic; yet, as of 2019, only 3.6% of medical school faculty are Black and 3.2% are Hispanic (AAMC, n.d.; U.S. Census Bureau, 2024). This disparity will likely grow given recent demographic trends in the general U.S. population. Numerous interventions have been attempted at the undergraduate, post-graduate, and faculty levels, but the pace of expanded representation in the sciences has neither closed historical gaps nor has it kept pace with U.S. demographic changes (Hurtado et al., 2017).

Closing the gap in representation at all career levels is key to addressing health disparities and improving public health policy, and hinges upon recruiting and retaining a diverse workforce (Dorsey et al., 2010; Martinez et al., 2022; Ward et al., 2022).

To leverage the existing infrastructure already providing broad biomedical research experiences to undergraduate students, DDF invited universities, medical schools, and research institutions with existing internship programs to apply for funding to support introductory research experiences for HS students from groups underrepresented in the biomedical research workforce, defined previously by the National Institutes of Health as individuals who are low income, first in their families to attend college or otherwise underrepresented in science (URS). Out of the call for proposals, the Sponsor selected eight institutions as participating sites over the last ten years. Sites were initially chosen based on their research training expertise, supportive institutional environment, faculty experience in mentoring youth, and broad range of possible research experiences appropriate for the training of high school students. Here we describe the results of this national program that has allowed participating sites to build upon their institution-specific strengths to provide optimal research experiences and career exposures to URS HS youth.

Unique to this sponsored CRC program is the collaboration that was encouraged among sites to work together to extract key elements most beneficial to successful student training. This was facilitated through annual in-person retreats and frequent Zoom calls among DDF staff, program directors, and support staff. The CRC program provides resources for site personnel to coordinate experiences as well as identify and recruit students from target demographics. It also supports mentor and student stipends, social support networks, and enrichment activities, including college preparation. The program is particularly geared toward students who may be unable to participate in unpaid research experiences or college admissions counseling due to family income limitations. Here, we provide the similar and distinct elements of research experience structures across the program's participating sites, along with participating student characteristics. We also report findings from a short-term assessment of student skills gained that was administered immediately following the research program experience using a self-evaluation approach.

METHODS

The CRC program has the goal of "increasing the diversity of the biomedical research workforce through providing students with engaging, valuable experiences in the sciences that cultivate their interests towards careers in biomedical research" (Doris Duke Foundation, n.d.). Eight centers were funded by this mechanism (see details in Acknowledgements): Arthur Ashe Institute for Urban Health (Arthur Ashe), Bradley University (Bradley), Children's Hospital of Los Angeles (CHLA), Charles Drew University of Medicine and Science (DREW), University of Pittsburgh (Pittsburgh), Stanford University (Stanford), UCSF Benioff Children's Hospital Oakland (UCSF) and the University of Wisconsin (Wisconsin).

Data presented herein represent results across all sites from 2012-2021. Additionally, in 2016 the CRC program expanded to offer alumni the opportunity to participate in the program again while an undergraduate; outcomes from those experiences are noted. In 2020, three of the eight institutions needed to briefly suspend their programs and others moved to distance learning due to the COVID-19 pandemic. Responses of students in the 2020-2021 cohorts were included in analyses. The details regarding specific curricula developed during the pandemic for these programs were previously published (Fung et al., 2021).

Student Surveys. DDF developed and analyzed a 41-question entrance survey, and a 30-question exit survey for students. The online entrance and exit surveys were distributed to students by program directors during the first and last weeks of programming (see Appendices). Individual responses were not shared with sites and all data were stored by DDF on a secure network. In order to encourage collaboration and reduce competition among CRC funded sites, DDF chose to maintain full administration of the survey and its analysis, and discouraged presentation of findings by center. This evaluation, involving the use of survey data, was determined to be non-clinical quality improvement by the UCSF Institutional Review Board. As such, the program evaluation was exempt from review by the Institutional Review Board process.

Of the 793 students who were in the program between 2012 and 2021, 706 participants completed both the entrance and exit surveys (pre-and post-program surveys). Of the 706 pre-post matched survey responses, 685 had complete data on participant demographics, satisfaction, and parent/guardian occupation(s) as some students declined to self-report ethnicity, gender, or parent information. Results from 658 students were analyzed for attitudes toward STEM and motivations to participate in the program while 566 had data on a before-and-after assessment of research and professional development skills; these two categories of questions were added to the surveys after the programs were initiated in 2012 (Figure 1).

Underrepresentation. Sites recruited students from communities underrepresented in the biomedical research workforce using the previously published National Institutes of Health criteria (NIH, 2019). This definition included indi-

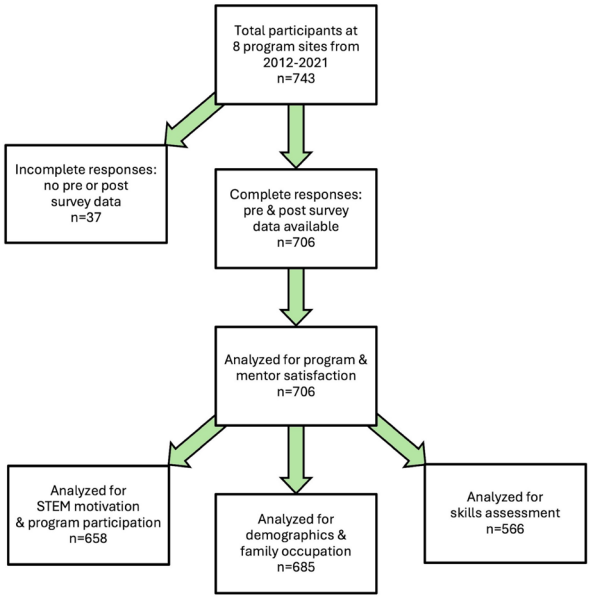

Figure 1. Summary of Survey Responses Received for Students who participated in Doris Duke Foundation Clinical Research Continuum (CRC) Programs at 8 U.S. sites between 2012 and 2021.

viduals from racial and ethnic groups historically underrepresented in STEM, as well as students who came from disadvantaged or low-income households, had a chronic disability, or were first in their family to attend college. Sites were given permission to also include groups convincingly demonstrated to be underrepresented by the grantee institution. In 2021, the program definition of underrepresentation was expanded to include gender diversity including transgender, non-binary, and gender non-conforming students.

Demographic Information. Optional information about students' race and ethnicity, gender, grade level, and parental educational attainment was also collected from participant surveys. From 2014 onward, respondents were given the option to self-identify race, and in 2020 onward, their gender preference. To assess parental education, students were asked to indicate the highest level of education of Parent 1 and, if applicable, Parent 2. Responses were compared and the most advanced degree between the parents was used.

Interest in Higher Education and Knowledge of STEM Careers. Students were asked about prior exposure to healthcare and research careers through family members and whether they were planning to pursue undergraduate or graduate degree education.

Motivation for Applying to the Program. Students were asked to indicate the extent to which their decision to participate in the program was influenced by an interest in research, interest in healthcare, desire for increased competitiveness for college or graduate school, opportunity to spend the summer at a participating site, or receipt of a stipend.

Knowledge and Skills Provided by the Research Experiences. The surveys assessed students' perceptions of their pre- and post-experience competence in understanding and applying the research/scientific method in 14 different skills (e.g., reading scientific literature, analyzing data). A five-point Likert scale was used for students to respond to each question from 'strongly disagree' to 'strongly agree' or from 'no experience' to 'extensive experience' depending on the question. Post program surveys queried students' attitudes regarding their change in knowledge or experience. The question asked, "How much experience/knowledge have you gained in the following" and students responded from "no gain or very small gain" to "very large gain."

Programmatic Satisfaction and Interest in STEM. The exit survey measured students' satisfaction with their overall experience, enrichment activities, project difficulty, and experience with their mentors. Students were also asked to assess the extent to which the program influenced their interest in pursuing research or healthcare careers using the same Likert scale as described above.

RESULTS

Program Characteristics. Participating sites were encouraged to develop curricula that leveraged local strengths, rather than confining programs to a sponsor-initiated framework. For example, one site focused their research with students on the intersection of cancer biology and computational science, while another focused exclusively on basic fundamental biology with particular emphasis on mechanisms underlying pediatric chronic disease. Examples of general research areas available to students at each site are provided in Figure 2. Regular communication and collaboration among sites were promoted by the DDF. Annual director's meetings hosted by DDF each fall allowed sites to share individual program strategies, successes, and challenges to student training and mentor support, while exploring possible solutions.

Commonalities were consistent in the broad structural experiences offered across all sites. Shared programmatic features included hands-on research experiences, enrichment activities, mentoring, opportunities for students to share their research, and a stipend paid to students (see detail Figure 3). Most HS programs ran for 6-10 weeks over the summer—a although one was yearlong--and those involving college students sometimes ran longer (9-12+ weeks). While mentoring strategies were also unique among sites, all instituted some degree of direct mentoring; some sites utilized faculty researchers, post-doctoral fellows, and teaching assistants while others utilized medical residents as the prima-

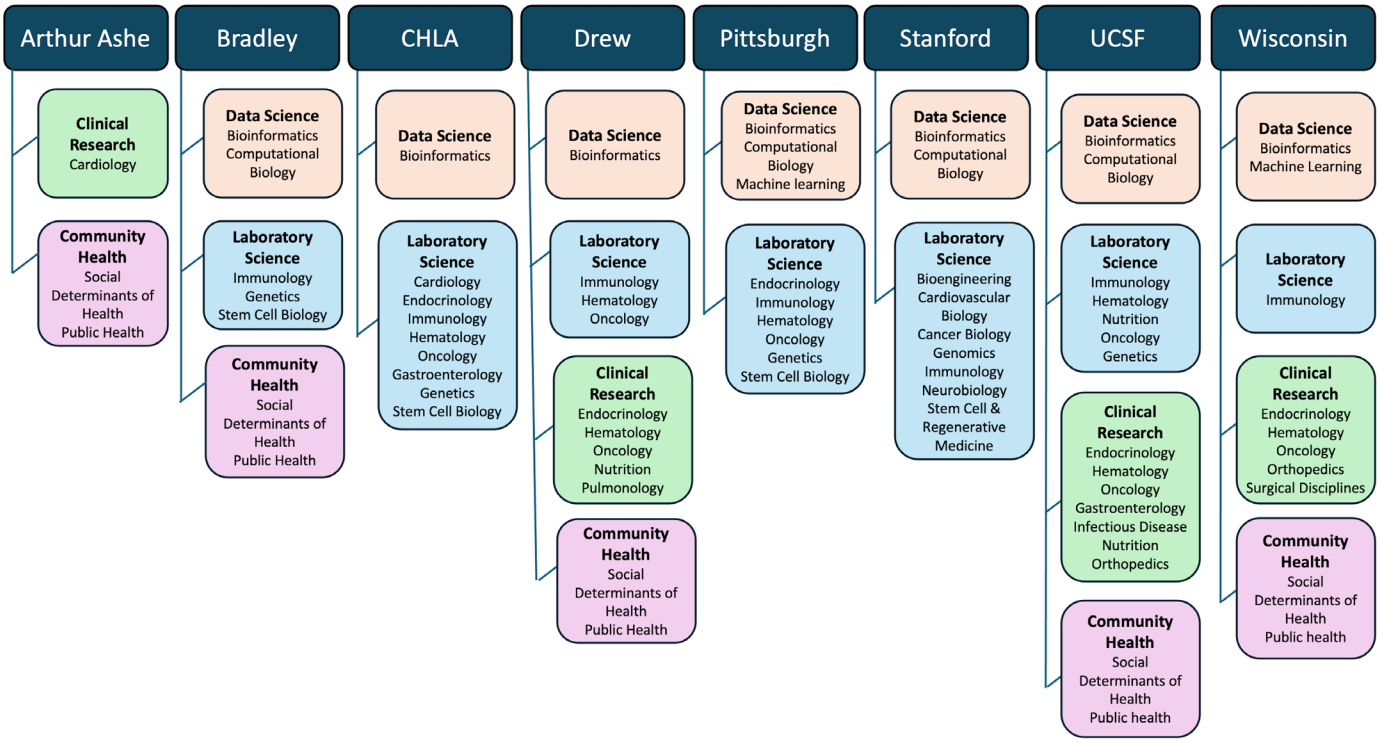

Figure 2. Main Research Focal Areas for High School Training within the eight Participating Clinical Research Continuum (CRC) Institutions.

ry student mentors. Furthermore, all sites utilized near-peer mentoring in some capacity, providing either high school to high school or undergraduate to high school student support. Survey data showed that 319 students (45%) were mentored in a team setting and 387 (55%) were mentored by an individual. Although mentoring approaches differed widely, survey data indicated that 88% of students were highly satisfied with the quality of mentorship they received and 84% reported satisfaction with sufficient access to their mentors.

Enrichment activities varied across sites but consistently focused on science education and skills. Activities included mini-modules, informal lectures, seminars, and structured discussions. Students were also given formal instruction in laboratory safety and equipment use, conducting literature reviews, reading and critiquing scientific articles, protecting human subjects, conducting research, and disseminating research findings. Areas of variation included training in the use of word processing, PowerPoint, and data analysis programs. All students had the opportunity to present their research through either poster sessions or oral presentations and most also had the opportunity to publish their research through institutional newsletters, program or national conference abstracts, and occasionally research manuscripts.

Student Characteristics. Most students were female (68%) and Hispanic, Latino/a, or Black (Table 1). The majority of HS students attended a CRC program after completing 11th grade (n = 434, 61%). Undergraduate students comprised a smaller fraction of the participants (n = 53, 8%) and tended to participate after completing one year of college. HS students reported various important or very important motivations to participate in the program, ranging from an interest in healthcare (n = 541, 79%), the opportunity to spend their summer at a research site (n = 432, 63%), an interest in research (n = 418, 61%), to sharpening their competitiveness for school (n = 392, 57%). The stipend was *very important* or *somewhat important* to the majority of students (n = 367, 53%). Participants' parents also varied in their educational attainment and jobs (Table 1) with education attainment covering a wide span. Strikingly, 46% of students would be the first in their family to complete an undergraduate degree. A substantial number of participants had parent(s) whose occupation(s) were related to health care in some way, while relatively few parents worked in science or science related fields.

Student Skills and Experiences Gained. Most participants were appreciative of enrichment activities: 80% (n = 565) *strongly agreed* or *agreed* that enrichment activities were a significant program feature (Figure 3). One of the most common activities in which students participated across all sites was research presentations (n = 670, 95%) in the form of a poster session or research symposium.

Pre- and post-survey questions sought to assess participants' skills in various areas and revealed many self-reported gains. Prior to participating, 76% (n = 324) of the HS stu-

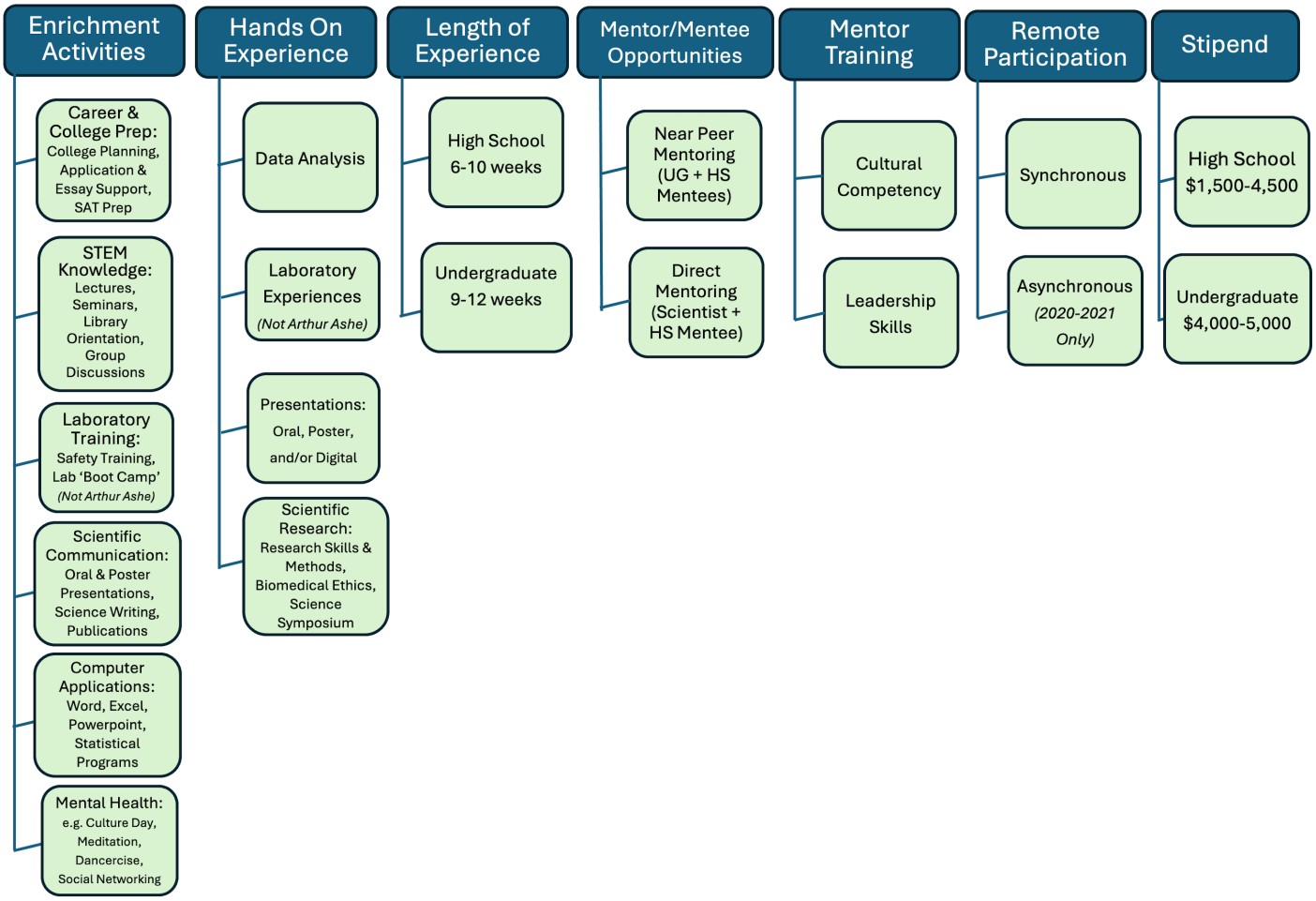

Figure 3. Similar broad programmatic characteristics across eight participating Clinical Research Continuum (CRC) institutions.

dents had no prior experience working on a research team. After completing the program, 88% (n = 501) of participants reported *moderate* to *very large gains* in collecting data, 80% (n = 453) in conducting statistical analyses, 86% (n = 492) in experience with oral presentations, 89% (n = 506) in confidence conducting literature reviews, 91% (n = 513) in reading scientific literature, and 91% (n = 516) in scientific writing. Additional *moderate* to *very large gains* were reported in interpreting scientific results (n = 526, 93%) and independent thinking (n = 522, 93%). The greatest skill transformations were moderate to very large gains in analyzing data (n = 535, 95%) and understanding the research process (n = 545, 96%) (Figure 4).

Student Satisfaction Across Sites. A striking continuity across sites was the high rate of participant satisfaction. Most participants, (n = 673, 95%), were satisfied with their program experience and agreed it was positive, with 71% (n = 499) of participants reporting the highest possible level of satisfaction. This sentiment tracked closely with the level of intellectual stimulation participants experienced whereby 81% (n = 572) felt their research projects were challenging. Similarly, 88% (n = 617) of participants reported satisfaction with the quality of mentorship they experienced. High levels of interaction with a mentor were also reported, with most participants reporting meeting either 1-3 times (n = 229, 32%), 3-5 times (n = 232, 33%), or more than 5 times (n = 215, 30%) per week.

Effect of the Program on Student Career Interests. The programs demonstrated significant positive impacts on participants' interest in pursuing careers in research. Prior to participation, 31.8% of students reported being very interested in a research career. Following the programs, this number increased to 37.1%, reflecting a clear upward shift. Notably, the proportion of participants who were only somewhat interested in research careers decreased from 44.8% to 38.1%, indicating that many students moved into the very interested category after completing the program. Overall, 78% of participants (n = 525) stated that the program positively influenced their interest in research careers, reinforcing the program's role in inspiring future researchers. Additionally, 76% (n = 535) reported an increased interest in healthcare careers.

Table 1. *Demographics and characteristics of participating high school and undergraduate students in the Clinical Research Continuum Training Program between 2012 and 2021.*

Total Number of Students	706
Gender	
Male	212 (30%)
Female	482 (68%)
Nonbinary/Other	2 (<1%)
Unknown	10 (1%)
Racial Identity	
Black	241 (34%)
Asian	112 (16%)
White	101 (14%)
Mixed	67 (9%)
Other Racial Group	56 (8%)
American Indian	6 (1%)
Native Hawaiian, Pacific Islander	4 (1%)
No response	119 (17%)
Ethnic Identity	
Hispanic/Latino(a)	274 (39%)
Non-Hispanic	421 (60%)
Unknown	11 (1%)
Parent Education	
High School Diploma	196 (28%)
Some College	128 (18%)
College Degree	109 (15%)
Post Graduate Education	209 (30%)
Unknown	64 (9%)
Family Occupation ^	
Healthcare	318 (46%)
Science	94 (14%)
Other	273 (40%)
Previous Research Experience*	24%
Students Motivation to Participate in Program**	79% Healthcare Interest 61% Research Interest 57% Improve Competitiveness for College 23% Funding Support

Note: all undergraduate students (n=53) had previously participated in the program as a high school student, these students repeated the program as alumni, and at most sites engaged in near-peer mentoring activities in addition to their individual research experiences.
Parent education attainment: highest level of education of either parent/guardian
**Previous research experience question only asked of high school students*
^Family occupation: at least one family member in the stated career
***Prevalence of responding 'very important' to these motivations for participation in program*

DISCUSSION

The goal of the CRC has been to support clinically relevant research experiences for URS HS students that will foster interest in careers in biomedical research careers (Doris Duke Foundation, n.d.). Survey results captured over a decade from 8 different programs across the country demonstrate success in this goal. Universities and medical research institutions are uniquely positioned to engage HS students with modern laboratories, advanced technology, and faculty, trainee, and staff role models (Winkleby et al., 2014). Participating sites have demonstrated effective ways to structure meaningful research experiences for URS HS students. How participating sites carry out the shared commonalities of hands-on research, mentoring opportunities, and enrichment activities is dependent upon their areas of expertise and institutional culture, but all were successful. The diversity of the research experiences is a strength of the collaborative CRC model because sharing passion, enthusiasm, successes, and challenges allow for improvements across sites to ignite interest in biomedical research among URS learners.

Comparisons in Structural Experiences. All participating sites offered broadly similar structural experiences that included active research, data collection or analysis, enrichment activities, and mentoring. Yet a degree of variation was observed in how sites executed their programs. All sites tailored their program to rely on their strengths, which accounts for heterogeneity in experiences among sites. Sites also developed enrichment activities and college or academic preparation programs in direct response to the needs and interests of their participants collected during the application process, ranging from computational data analysis to wet-lab basic, clinical, and translational research. Given the heterogeneity of HS science education and the type of research experiences offered, sites tailored their enrichment activities to accelerate basic knowledge acquisition needed to conduct research within their focal area of expertise. As examples, one site with expertise in data science offered an introductory statistical coding workshop in R, while another site with experience in the translation of basic science to clinical fields offered a workshop for students to practice basic CPR and IV placement in teaching mannikins. This format allowed programs to be responsive to the individual HS students from their respective areas and level of scientific literacy.

The data indicated satisfaction with program-provided mentorship. Sites designed their mentoring activities to best engage their students and optimize for a supportive environment. Near-peer mentoring was identified early in the CRC program development to be a critical part of the curriculum. Near-peer mentoring may have improved communication and allowed for inexperienced students to feel more confident asking questions of someone more similar to themselves in age and experience than a PhD student or faculty member. It may also have allowed for more frequent mentor-mentee interactions, since time with a more seasoned researcher was less available given professional duties.

Participant Characteristics. All students who participated in the CRC program were underrepresented in the biomedical sciences by at least one of the criteria previously defined by the NIH. More than half of HS students participated in the

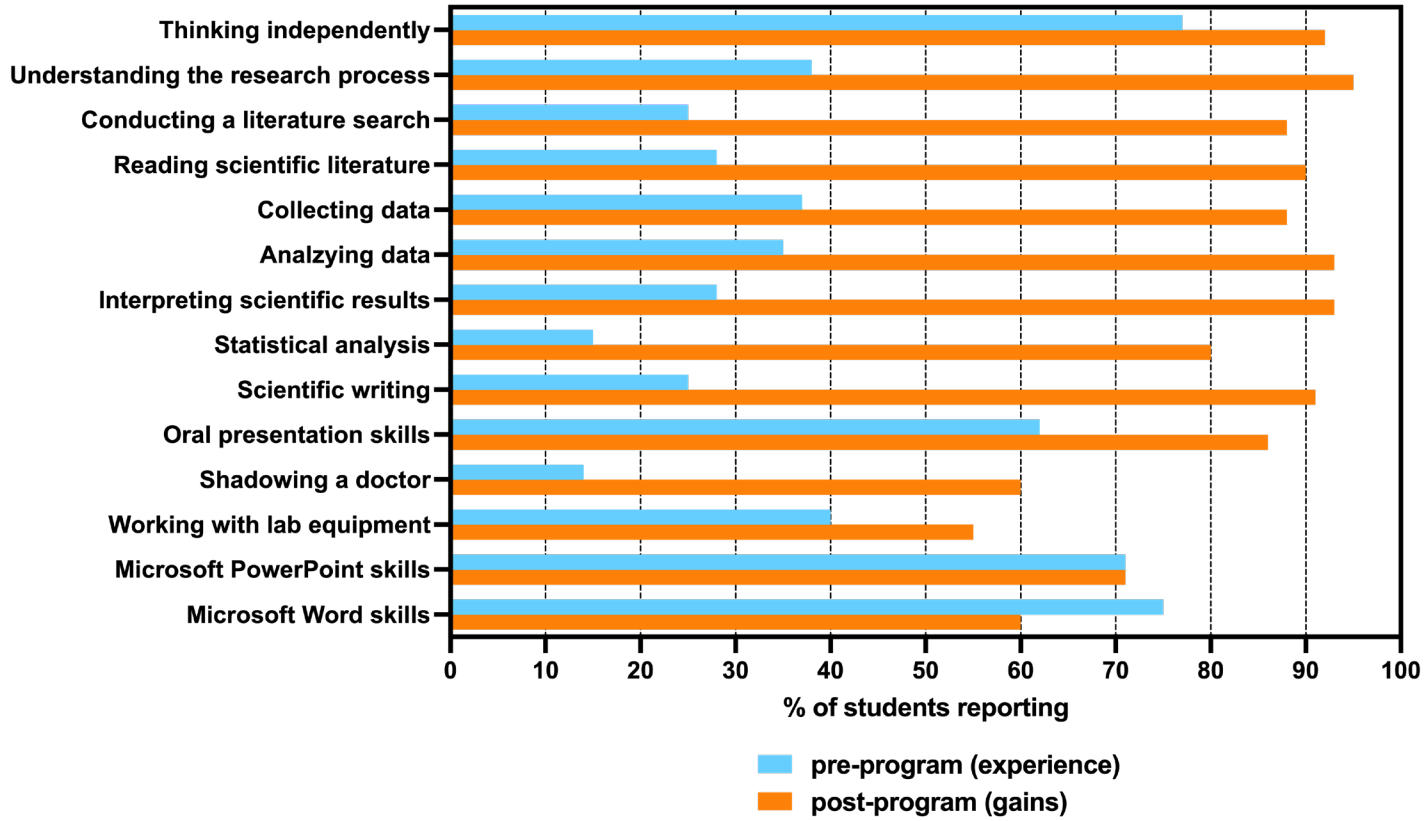

Figure 4. Student Baseline Survey Responses (Pre-Program: Blue) Combined with Post-Program (Orange) Survey Responses for 14 Key Scientific Skills Developed Over the Course of the Clinical Research Continuum (CRC) Training Programs (2012-2021). Percentage of total students reporting some to extensive current experience in mastering the skill (pre-program response) compared with moderate to large gains in mastering the skill at the conclusion of the training program (post-program response).

summer after their junior year, which is likely attributed to institutional age restriction policies and may coincide with a heightened sense of awareness for preparing for college applications and next educational steps. Among the undergraduate alumni, the bulk of students participated in the summer before their sophomore year, which reflects a timeframe when choices are typically made to declare majors. Students at this early stage are also less competitive for the limited undergraduate science training programs, therefore the CRC program fills an important gap by keeping students engaged in research at a critical time in their science identity/career trajectory.

What Participants Gained. The data show consistent gains in students' self-assessed efficacy across a broad set of skills in all sites despite variation in program structures. These results support the value of a model that emphasizes authentic research experiences, mentorship, and communication of shared expertise across sites while allowing individuals to tailor their programs to leverage local strengths. Sites optimized their college readiness activities for participants according to their needs for standardized testing, college applications, and writing college essays. One site focused on exam preparation and was able to identify and provide tools to students who did not have appropriate test-taking materials. Other sites focused on admissions counseling, financial aid, and navigating student services on campus.

Limitations of this Report. The eight participating CRC sites represent diverse academic institutions across a broad geographic range. They do not, however, include academic institutions from the Northwest or Southern U.S. regions which have their own distinct student populations. Additionally, the evaluation depended on self-reported data from the participating students. It was not possible to objectively determine the validity of these data, however similar surveys have been previously examined and validated (Weston & Laursen, 2015). Therefore, it is likely that gains in scientific skill development reflect positively on self-confidence and science identity. Furthermore, the survey administration and data analyses were performed by the funders, who to encourage cooperation instead of competition did not release site-by-site results. However, they confirm that the results were consistent across programs which suggests the focus on authentic mentored research with modifications to specialize to individual student populations and locations is a robust way to encourage participation of URS students in research careers.

CONCLUSIONS

The CRC program has provided a template for a collaborative, coordinated, and sustained national effort to support HS bridging programs with universities and medical research institutions to mitigate the racial, ethnic, and gender diversity gaps within the biomedical field. As with previous reports (Chuisano et al., 2023; Crump et al., 2014; Kadavakollu et al., 2020; McKendall et al., 2014; Patel et al., 2021; Rivers et al., 2020; Salto et al 2014; Winkleby et al., 2014), our analysis found a strongly positive impact amongst HS students from engaging in hands-on research experiences capable of influencing career aspirations and fostering an increased interest in science careers. Similar results have been found by other programs (Tai et al., 2017), with indications for increased retention in undergraduate science majors, a greater desire to attend graduate or medical schools, and to have a positive correlation with matriculating to graduate or medical school.

The CRC program has effectively targeted and engaged with URS HS students to spark interest in biomedical research and healthcare careers. It has been particularly effective at reaching participants who are Black and female, identify as Hispanic/Latino/a or who may have not had pre-existing exposure to careers in healthcare. The CRC program has provided participants with the time, resources, and access to deepen their engagement with, and knowledge of, the medical research field. It has effectively seeded interest at a critical node linking HS to college and STEM careers. Key aspects that contributed to the program's success included collaborations among sites to provide adaptive and responsive enrichment activities, college preparation and application assistance, flexible mentoring models, and a stipend. Because the CRC program's model allowed participating sites to leverage their expertise, it built engagement in an adaptive, decentralized, creative fashion that allowed each site to provide programming that suited both the local institution and the needs of its area HS students. Additional areas of future research include collecting longitudinal data on participants to further track the influential nature of the CRC program upon matriculation rates, the proportion of STEM degrees earned, and participant retention in the biomedical research field post-college to further clarify the importance of providing sustained support and training for students to keep them engaged in the STEM pipeline. We intend to examine these downstream effects of the program in a future publication.

ASSOCIATED CONTENT

Supplemental material mentioned in this manuscript can be found uploaded to the same webpage as this manuscript.

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Author Contributions

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

Note that all the work was performed, analyses completed, and first draft of this manuscript submitted prior to the 20 Jan 2025 executive orders regarding DEI programs and the use of specific language regarding race/ethnicity, gender or diversity.

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ABBREVIATIONS

CRC: Clinical Research Continuum; DDF: Doris Duke Foundation; HS: High School; NAESM: National Academy of Sciences, National Academy of Engineering, & Institute of Medicine; URS: Underrepresented in Science

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