# Establishing a STEM Summer Research Program for Underrepresented Minority Students

Kristin L. Morgan Jasmine Crenshaw Marcus L. Martin
University of Virginia

## Abstract

The proportion of underrepresented minority (URM) students graduating with Science, Technology, Engineering, and Mathematics (STEM) degrees, matriculating to graduate programs, and entering the STEM workforce continues to be significantly low. The Virginia–North Carolina Louis Stokes Alliance for Minority Participation (the VA–NC Alliance) (National Science Foundation-funded award #1712724) offers recruitment, retention, and enrichment activities tailored to meet the needs of URM STEM students with the goal of reducing this gap at its individual partner institutions. One of the VA–NC Alliance's signature activities is its summer research program. While discussing relevant literature, program design, methodology, and results, this first article about the VA–NC Alliance Summer Research Program explains our program design and describes the methodology and results of an initial assessment utilizing an alumni survey. Then, it presents lessons learned framed as challenges followed by recommendations regarding how to establish an impactful undergraduate research program that supports tangible outcomes for URM STEM participants from schools in the region, including Historically Black Colleges and Universities (HBCUs), community colleges, and Predominately White Institutions (PWIs). The next article will assess the program outcomes more in-depth and over a longer period of time.

## Introduction

The Virginia–North Carolina Louis Stokes Alliance for Minority Participation (the VA–NC Alliance) offers recruitment, retention, and enrichment activities tailored to meet the needs of underrepresented minority (URM) students enrolled in its individual institutions. The VA–NC Alliance is one of over forty Louis Stokes Alliances for Minority Participation (LSAMP) programs across the country sponsored by the National Science Foundation (NSF). The University of Virginia (UVA) leads the VA–NC Alliance that includes eleven other partner institutions one of which is a federal research laboratory: Bennett College, Elizabeth City State University, George Mason University, Johnson C. Smith University, National Radio Astronomy Observatory (NRAO), Old Dominion University, Piedmont Virginia Community College, Saint Augustine's University, Thomas Nelson Community College, Virginia Commonwealth University, and Virginia Tech. Partners leverage resources to yield an increase in the number of URM students who obtain science, technology, engineering, and mathematics (STEM) baccalaureate degrees. Due to varied resources at each institution, the VA–NC Alliance promotes specialized academic and professional development activities, including an annual symposium, graduate school preparation workshops, colloquia, mentoring, tutoring, and undergraduate research experiences.

In 2009, the VA–NC Alliance principal investigator and program director observed few VA–NC Alliance students participated in the highly competitive Research Experiences for Undergraduates (REUs), even REUs hosted at VA–NC Alliance partner schools. Thus, the VA–NC Alliance established the Summer Research Program in 2010 to provide research opportunities to participants to increase their competitiveness for REU programs and prepare them for graduate school. This paper discusses relevant literature, program design, assessment methodology as well as results, and lessons learned framed as challenges and recommendations regarding the development of URM STEM undergraduate summer or supplemental research programs.

## Literature Review

### Underrepresentation in STEM

While in the United States the demand for employees with scientific and technical competencies continues to grow, the STEM workforce has not diversified to reflect the changing demographics of the country. Underrepresentation of minority students in STEM majors and the workforce persists as an issue in the U.S. (Chen & Soldner, 2013). It is widely understood that a diverse workforce will be beneficial to solving complex societal problems (McGee Jr et al., 2012; National Science and Technology Council, 2000). Low numbers of ethnic and racial minorities in both STEM education and in the workforce are troubling, given concerns about the United States' decreasing productivity, innovation, security, and global competitiveness (de Cohen, 2006; Tull et al., 2012; U.S. Department of Commerce, 2012). Federal agencies and private organizations have allocated significant financial and human resources to increase representation in STEM (Alfred P. Sloan Foundation, 2020; Gonzalez & Kuenzi, 2012; Institute of Medicine, 2011; National Institute of Health General Medical Sciences, 2020; National Science and Technology Council, 2011; National Science Foundation, 2017, 2020; U.S. Congress, 2011). The NSF is one of the federal agencies that combats low participation of United States citizens in science and engineering by providing educational and employment opportunities to previously marginalized groups in those fields (de Cohen, 2006). Over the past twenty-five years, the NSF-sponsored Louis Stokes Alliance for Minority Participation (LSAMP) program has supported undergraduate URM students. The number of Bachelor of Science degrees earned by underrepresented students enrolled at LSAMP institutions across the nation increased from 4,093 in 1991-92 to 82,507 in 2018-19 (National Science Foundation, 2018-19). These participants went on to exceed national comparisons in academic performance (Clewell, 2006; de Cohen, 2006).

### Undergraduate Research Programs Designed Primarily for URMs

Undergraduate summer research programs have demonstrated several benefits pertaining to retention, matriculation to graduate school, and career interests. Students who have participated in summer undergraduate research have shown gains in independence, intrinsic motivation to learn and active participation in subsequent courses, deepened knowledge of how to conduct a research project, clarified interests in and further commitment to STEM careers, and increased anticipation regarding doctoral degree attainment (Lopatto, 2007; Perna et al., 2009; Russell et al., 2007; Seymour et al., 2004). Other benefits associated with undergraduate research experiences include expanded awareness of what a career in scientific research would involve (Kardash, 2000; Kinkead, 2003; Lopatto, 2004), clarified graduate school or career plans (Hurtado et al., 2009; Sabatini, 1997), GRE preparation (Dahlberg et al., 2008; Ghee et al., 2016; Page et al., 2004), graduate school preparation (Ghee et al., 2016), and increased self-efficacy in STEM coursework (Hurtado et al., 2009; Mabrouk & Peters, 2000). STEM Intervention Programs (SIP), such as LSAMP, were developed to provide access to undergraduate research, among other opportunities, resulting in increased persistence in their academic

pathways, including success in graduate school (Nnadozie et al., 2001; Olson & Riordan, 2012; Russell et al., 2007; Walters, 1997). LSAMP focused on URM students as its targeted population.

Administrators of SIPs have discovered best practices based on community building and collaboration to effectively aid in the retention and completion of underrepresented students in STEM (Dyer-Barr, 2014). Ideally, these administrators recognize the importance of the academic and social support that contribute to a sense of belonging. By being student-centered and learning from student interactions, SIP administrators contribute to retention (Institute of Medicine, 2011; Tinto, 2012). In addition, the consortium model of LSAMP promotes the development of a broader community, student-centeredness, and sense of belonging through its national conferences at the NSF Joint Annual Meetings, the Louis Stokes Midwest Regional Center for Excellence annual symposia, research experiences, and NSF Bridge to the Doctorate graduate recruitment opportunities.

Strong mentoring practices are essential to increasing the number of STEM graduates, particularly in underrepresented populations. The faculty-student mentoring relationship is a critical factor contributing to underrepresented minority students, including those enrolled at Historically Black Colleges and Universities (HBCU), matriculating to graduate school at higher rates (Gasman & Nguyen, 2014; McGee Jr et al., 2012; Perna et al., 2009). Faculty from Saint Augustine's University, one of the VA–NC Alliance partner schools, describe the mentor's role as one that "is not necessarily a long-term position nor is it a single-occupied position" (McClinton et al., 2018, p. 171). Offering multi-tiered mentors, also known as programmatic mentoring, is defined as "mentoring that is provided synergistically from multiple sources within a training program with a shared goal around student success in research, skills, academic performance, career planning and development, and personal growth" (McClinton et al., 2018, p. 240).

## VA–NC Alliance Summer Research Program Design

### Program Goals

The VA–NC Alliance summer research program goals were developed in the context of a public, Predominantly White Institution (PWI) research enterprise and we recognize that organizational cultures and structures vary. The VA–NC Alliance Summer Research Program supports the goals of its sponsor, the NSF to broaden URM participation in STEM professions by increasing the number of bachelor and advanced degrees earned at its partner schools. Short-term goals concentrated on (1) creating opportunities for students from each of the partner schools to engage in research; and (2) 100% retention in the summer program. The long-term goals of the summer research program included participants: (1) obtaining additional research opportunities beyond the VA–NC Alliance Summer Research Program; (2) graduating with a STEM degree; (3) matriculating to graduate school in a STEM field; and (4) entering the STEM workforce. These goals served as metrics for student success and guided personnel during the planning and operation of the program. To measure program success, feedback would be elicited from Alliance summer research program alumni via surveys.

In order to meet the VA–NC Alliance Summer Research Program's goals, summer undergraduate researchers had access to a network of multi-layered mentors: faculty, graduate students, staff members, and peers from partner schools. In addition, through partnerships with the Office of Graduate and Postdoctoral Affairs and the Office of Undergraduate Research summer researchers were afforded the opportunity to present their research findings at conferences. Through this collaboration the summer researchers participated in sessions regarding presentation and communication skills, graduate school preparation and funding, as well as other professional development opportunities. Finally, the VA–NC Alliance leveraged resources and opportunities to cultivate a supportive environment and learning community for students from partner schools.

### Faculty Mentor Identification and Training

Faculty mentors are an essential component of the summer program, providing students with an innovative research experience. VA–NC Alliance staff identified faculty mentors for the summer research program in several ways. Initially, faculty in STEM fields who had previously expressed or demonstrated an interest in working with underrepresented minority students were invited to participate in the summer research program as mentors. Subsequently, when faculty requested letters of support for proposals to funding agencies that required a commitment to broadening participation in STEM, the VA–NC Alliance asked faculty to provide research experiences for Alliance students. In some cases, faculty included funding for the student stipends in their proposal budgets. Later, we expanded the range of research tracks available by identifying faculty members in fields that weren't represented in the program by browsing departmental websites and contacting STEM professors highlighted in UVA press releases for their research or mentoring.

To facilitate a positive mentoring experience, the VA–NC Alliance Summer Research Program, in collaboration with the Diversity Programs in the Office of Graduate & Postdoctoral Affairs, offered the faculty mentors and their graduate students an orientation prior to the arrival of the students. This orientation outlined faculty/student expectations, the stipend installments, housing accommodations, and the students' professional development and social activities schedule. The orientation strived to address any potential communication issues and climate concerns about the university and research laboratories. Also, concepts such as diversity, equity, inclusion, cultural competencies, mentorship, bias, micro-aggressions, and representation were illustrated through several case studies. Faculty and their graduate students were engaged in discussion about the case studies and encouraged to share how a situation could have been made more inclusive. Given their role in teaching undergraduates about laboratory techniques and use of equipment, it was essential to have graduate students participate in these discussions.

### Student Selection

The VA–NC Alliance program director and coordinator routinely communicated with faculty mentors and program coordinators at partner institutions to promote the summer research program and recruit applicants that were rising sophomores through seniors. These email correspondences with personnel at the partner institutions were an essential part of the selection process of the VA–NC Alliance summer research program. In addition to the required letter of recommendations, , faculty from their home institutions occasionally confirmed students' motivation and research abilities via phone call or email.

Alliance personnel developed a rubric to evaluate summer program applicants and shared that with faculty mentors. Using a holistic review, the rubric examined multiple factors for consideration such as prior research experiences, research interests, GPA, graduate school intentions, and community service. Personnel decided to add community service to the rubric in order to elevate applicants who may not have had the highest GPAs yet had a passion for service. Positive outcomes associated with service-learning benefit students along a number of dimensions including academic performance, leadership, and self-efficacy (Astin et al., 2000). Students who demonstrate concern for their local communities may be able to appreciate the translational impacts of their STEM knowledge and skills to help solve critical problems facing their neighborhoods, regions, nations, and world. After considering these factors, we discovered that UVA faculty mentors were frequently willing to support these students in their labs, supplementing knowledge and skills as needed. The faculty mentors valued the application's holistic approach to student selection.

### Program Curriculum

VA–NC Alliance partner schools offered varied research and mentoring experiences, depending on available resources (e.g., facilities, labs, and equipment). Minimal exposure to these resources can impact student skill development, competency, and proficiency using laboratory techniques and equipment. The VA–NC Alliance Summer Research Program provided equitable access to resources through a holistic research experience. The program curriculum supplemented the research experience with professional development opportunities, social ac-

tivities, as well as graduate school and career preparation.

Similar to a typical work week, students were expected to work approximately 40 hours per week on their research projects as directed by the faculty and graduate student mentors and professional development activities – this expectation was communicated in the application as well in orientation. In addition, the summer research program offered both required and optional professional development opportunities with the following goals: expanding students' skillsets, exposing them to STEM graduate school and career options, and building their self-efficacy with regard to writing results and presenting research. Program staff decided to require the essential professional development activities (e.g., orientation, lab safety and research ethics trainings, writing workshop, a GRE preparatory course for rising juniors and seniors, weekly speaker series, presentation events) and offered optional activities for those students who chose to enhance their summer experience. The goals for the optional activities included: developing presentation skills, learning about etiquette, socializing, and practicing self-care). The weekly speaker series featured: a graduate student panel, academic and industry partners who spoke about their career trajectories, and a panel of faculty representing admissions committees. The social components of the program (e.g., ice cream social, 4th of July cookout, free wellness classes, field trip to a local amusement park, bowling, and movie viewing parties) included researchers from various summer research programs on campus to build a broader sense of community.

Summer researchers were provided with crucial opportunities to practice speaking publicly about their research. Throughout the summer, students participated in a variety of presentation formats including: "chalk talks" during which they explained their projects to program staff and peers; lab meetings with faculty, graduate students, and peers; and the "Three-Minute Thesis" (3MT) in which students learned how to condense their work into a shortened, elevator speech. In preparation for their final presentations, VA–NC Alliance participants also engaged in a "Pizza & Presentations" session, where they practiced presenting their research projects via an oral or poster format. Presentations were conducted in an informal environment to an audience of fellow STEM and non-STEM researchers at UVA. Each year the VA–NC Alliance summer research program culminates with the Leadership Alliance National Symposium (LANS) where students give their final presentations. LANS typically hosts over 700 undergraduate and graduate student presenters, faculty and administration staff from across the nation. Students are encouraged to present their research projects back at their home institutions and to seek opportunities to present at other national conferences.

| Race/Ethnicity | Male students | Female students | Gender queer/Gender Non-conforming |
|---|---|---|---|
| Black or African | 6 | 14 | 0 |
| Hispanic or Latino | 2 | 3 | 0 |
| Asian | 1 | 1 | 0 |
| Multi-race | 0 | 2 | 1 |
| **Total** | **9** | **20** | **1** |

**Table 1. Demographics of Survey Respondents**

## Method

### Participants

The success of the VA–NC Alliance Summer Research Program was assessed by a survey of summer research program alumni who were enrolled as undergraduates at Alliance partner schools. All 69 alumni of the program from 2010 to 2017 were invited by email in fall 2017 to participate in a one-time survey. Thirty out of 69 alumni responded to the 2017 survey, providing a response rate of 43%. The length of time between participation in the summer research program and responding to the survey varied among respondents. The majority of respondents ranged from 18 to 22 years old at the time of their participation in the summer program. Most summer research program alumni and survey participants were African American and female, as demonstrated in table 1 (Author 2 & 1, 2017).

### Procedure

The alumni survey was distributed by emailing a link through the online survey platform Qualtrics, and reminder emails were issued to recipients who had not responded. In addition, partner school personnel forwarded the survey request to alumni when valid email addresses were unavailable. The survey asked about subsequent research experiences, undergraduate and graduate school enrollment and degree status, graduate fellowships awarded, STEM career aspirations, employment status, and demographic questions. Although program staff members were aware of additional information about alumni achievements (e.g., social media, direct communications), the research team only analyzed the alumni survey responses, assessing metrics associated with the primary goals of the summer research program.

## Alumni Survey Results

### Subsequent research experiences

The VA–NC Alliance summer research program was designed to position its alumni as competitive applicants for research intensive experiences. To assess this metric, respondents were asked: "In addition to the VA–NC Alliance Summer Research Program, have you had other undergraduate research experiences outside of course labs?" As illustrated in Figure 1, 20 out of 30 respondents reported engagement in additional research opportunities, both formal and informal, after the summer program (e.g., REUs, research assistant to a professor, intern in industry lab, etc.) (Author 2 & 1, 2017).

One summer program alumna reflected on her experiences at the National Radio Astronomy Observatory through the VA–NC Alliance Summer Research Program, saying:

> LSAMP afforded me the opportunity [to] pursue my passion in astrobiology. During that summer, I gained knowledge in radio astronomy and built relationships with my mentors who in turn have continued to help me along the way . . . I have presented at numerous conferences the most significant being the AAS where I was named a 2018 Chambliss Astronomy Achievement Student Undergraduate Honorable Mention. Since completing my undergraduate studies, I have been a Research

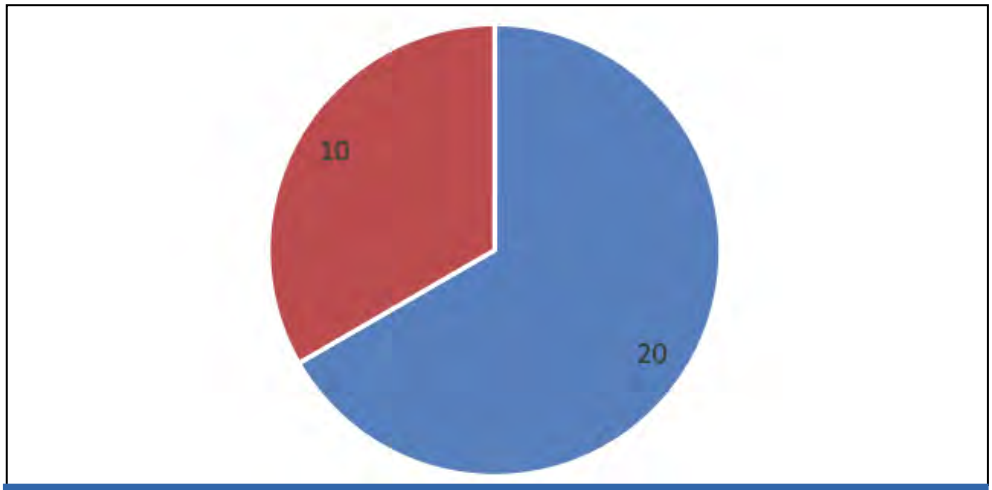


**Figure 1. Survey Respondents that Participated in Additional Undergraduate Research Experiences Outside of Course Labs**

| Graduate Program Classification | STEM Field | Non-STEM Field | Health/Medical |
|---|---|---|---|
| Enrolled master's program | 1 | 2 | 2 |
| Enrolled doctoral program | 5 | 0 | 2 |
| Earned master's degree | 2 | 0 | 0 |
| Earned doctoral degree | 0 | 1 | 0 |

Table 2. Postgraduate Outcomes of Survey Respondents

> Scientist at NASA Goddard in Maryland where I continue to work on exciting astrobiology research and am submitting graduate applications (Anonymous, personal communication, December 11, 2018).

She credits her participation in the VA–NC Alliance Summer Research Program for the mentorship she received, subsequent research and presentation experiences in the astrobiology field, and preparation for graduate school.

Another former summer researcher secured a long-term research experience as a research assistant to a professor in Disease Ecology at his home institution during the academic year for the remainder of his undergraduate career. Subsequently, at a different institution, this summer researcher participated in a Research Experiences for Undergraduates program and is currently a doctoral student and NSF Graduate Research Fellowship recipient. This former summer researcher shared the following reflection:

> My first research experience was with the VA–NC Alliance Summer Research Program at UVA in Astrochemistry and it was through this experience that I realized I wanted to pursue a career in research. Although I study disease ecology now, the lessons of team work and communicating science to different audiences are important skills that I learned through the program that I utilize daily in graduate school and will continue to use as I progress in my career. I am so thankful for the research program because it launched my trajectory into a career in science, and I would not be on this path today without it (Anonymous, personal communication, January 10, 2019).

### Graduate program matriculation and degrees

The survey also tracked alumni outcomes pertaining to graduate school and learned that former summer researchers had found success in graduate school and the workforce. Since the program's inception in 2010, seven summer program alumni enrolled in STEM graduate programs. Eight individual respondents out of 30 have either enrolled in a STEM graduate program and/or graduated with a STEM graduate degree. Table 2 illustrates that the VA–NC Alliance achieved a 27% success rate for STEM graduate program enrollment and/or degree attainment in a short period of time (Author 2 & 1, 2017). There were two respondents who enrolled in multiple graduate programs at the master's and doctoral level–they are included twice each in the table. Notably, three out of 30 respondents were awarded prestigious national STEM fellowships, including the National Institutes of Health Intramural Research Program, NSF Bridge to the Doctorate, and the NSF Graduate Research Fellowship. Furthermore, the Alliance's first STEM Ph.D. was earned by Racheida Lewis who was in the first summer research program and is now an Assistant Professor at the University of Georgia.

### Career plans

The survey also inquired about alumni career intentions. Out of the 30 respondents to the alumni survey, 28 confirmed their intent to work in a STEM field. This represents 93% of all respondents across all racial and ethnic groups, as illustrated in *Figure 2. Survey Respondents Planning to Work in a STEM Field.* Of the 93%, 90% of African Americans and 100% of Hispanic/Latinos, Asians, and Multi-race (minority) indicated their intent to work in a STEM field.

## Summer Research Program Challenges and Recommendations

Below we discuss the specific challenges staff experienced, and factors to consider during the development and implementation phases of a summer research program, along with recommendations to address these challenges.

### Collaborate with staff across campus(es)

Decentralized universities present challenges in identifying collaborators yet working together is essential to develop a successful program and avoid duplicating efforts. Institutions' sponsored programs offices are essential collaborators who delineate allowable expenses according to the funding sources (i.e. federal, state, private donors, corporate) and their regulations. During the start-up year of the VA–NC Alliance Summer Research Program, the coordinator of a longstanding program shared her expertise, relaying information about housing options, the university identification card procedure, and fiscal processes (e.g. recruitment and payment to residential advisors, student stipend installment requests, and software purchases). This partnership resulted in the establishment of a broader community with shared professional development and social opportunities including housing in the same residential hall, speaker series, and field trips.

Personnel representing university-wide summer initiatives routinely met in advance of the summer term to share information and resources, coordinate housing, and schedule joint activities. This created a wider community of students who were recruited to UVA through grants seeking to broaden participation and provided opportunities for undergraduates to experience a broader cohort of STEM summer researchers. Summer program orientation materials, mentor training, housing, GRE prep classes and curricula were shared as appropriate amongst programs. These collaborations expanded the professional development, networking, and social activities offered while saving time and costs.

### Develop multi-layered formal and informal mentoring model

Acknowledging that laboratory cultures vary, the common practices at a Research I (R1) institution, such as UVA, do not always cultivate an inclusive environment that meets student expectations of academic and social support. This is often true for students from small liberal arts colleges and/or HBCUs. In addition, there is an expectation within research intensive environments for students to work independently and/or within teams, although clear guidance is not always provided. This may contribute to student uncertainty regarding how to integrate themselves within a research group. When these institutional culture issues are not addressed, they can exacerbate feelings of impostor syndrome and impede the development of student STEM identity.

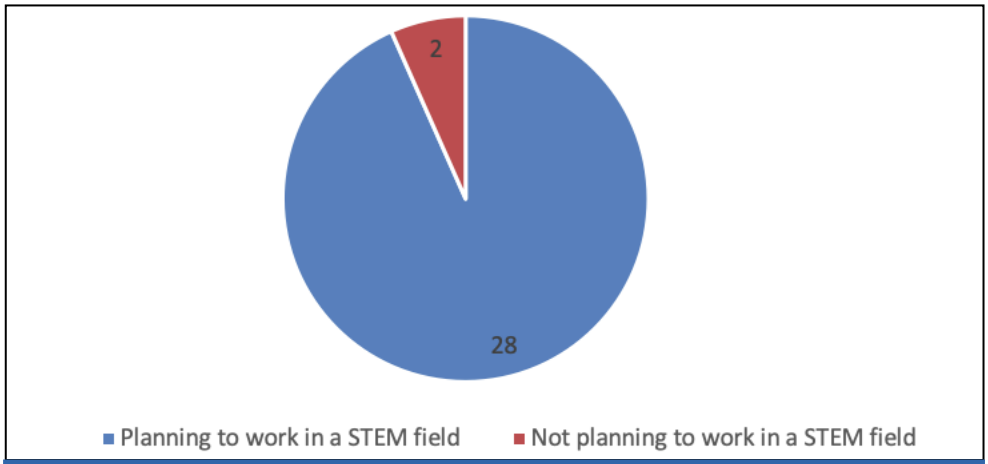


Figure 2. Survey Respondents Planning to Work in a STEM Field

Alliance personnel and students observed that some faculty and graduate students had little or no experience mentoring underrepresented students. Further, summer researchers occasionally shared (in individual meetings, mid-point check-ins, and following professional development sessions) that they perceived negative assumptions and biases regarding educational experiences at HBCUs and small liberal arts colleges. The lack of mentorship experience and biases in the faculty led to a disenfranchisement amongst participants. These combined factors negatively impact faculty-student interactions and the overall student experience.

To counteract these negative experiences, we discovered and implemented two changes: creation of a multi-tiered mentoring system, training, increased communications, and faculty surveys. We recognized that summer research participants benefit from multi-tiered mentoring through formal and informal approaches. These include faculty mentors at UVA as the research site, graduate students, post-doctoral students, program coordinators, peers, residential advisors, and guest speakers, each of whom may contribute to students' technical competencies, sense of belonging, and self-efficacy. On occasion, faculty from the summer researchers' home institutions, with whom the students have a prior relationship, have provided mentoring when students required additional support. Informal mentors helped students navigate relationships with faculty mentors by offering advice, providing support, and serving as liaisons to troubleshoot matters. Furthermore, students relied on each other and built community as informal peer mentors, while they adapted to new environments, learned new skills, and cultivated a STEM identity. Graduate students play a significant role in the multi-tiered mentoring model during summer research experiences. At R1 schools, graduate students are often held responsible for advising undergraduates about research content and addressing any knowledge gaps, spending many hours teaching essential concepts. This will help them support students with varied backgrounds and levels of preparation. Access to multiple mentors provided undergraduate students with alternative viewpoints and options when their primary summer research mentors were not readily accessible or a well-suited match, resulting in increased student persistence during the program.

After the third year of the program in order for the summer researchers to have a more consistently positive experience at UVA, we began requiring faculty and/or their graduate students, who typically serve as the formal mentors, to participate in an orientation and training session. During this faculty orientation and training, we reviewed program expectations and emphasized creating inclusive research environments; for example, Alliance personnel presented case studies to illustrate incidents of faculty bias and develop situational awareness among the faculty and graduate students. Furthermore, staff engaged with faculty regarding the impact of mentorship on underrepresented students, and how to incorporate mentoring tools into their day-to-day interactions with students.

In order to stay abreast of the student's progress and engagement with the research project, Alliance personnel began communicating more frequently with faculty during the summer program to identify concerns, troubleshoot, and ensure alignment amongst research mentors and students. We learned that both the faculty and their graduate students need to be alerted in advance of the program about the additional time commitments devoted to developing inclusive teaching and knowledge, skills, and abilities pertaining to mentorship. As an additional form of communication, the program began surveying faculty mentors following completion of the summer research program elicited useful feedback. One faculty member suggested hosting more informal gatherings with mentors and mentees (Author 1 & Walker, 2019). For example, the weekly lunchtime speaker series offered opportunities for summer researchers to engage with graduate students, faculty, and program personnel in a safe space where participants acknowledged their challenges and wins. During these sessions, participants occasionally revealed struggles and uncertainty relating to faculty, graduate students, and peers within the lab environment, inclusive of miscommunication, imposter syndrome, and perceptions of bias. Acknowledging the importance of a multi-tiered approach to mentoring, one faculty mentor observed in post-survey feedback, "Fortunately, he feels more comfortable talking with my grad student, and so I am depending on that intermediary relationship to make this summer successful" (Author 1 & Walker, 2019).

### Provide additional research-related opportunities during the academic year

Summer programs often provide undergraduates with a singular, short-term research experience that are valuable for students to learn complex thinking and decision-making, research design, and collaboration (Seymour et al., 2004). Continuous research experiences afford students additional opportunities to persist through long-term projects and publish findings. Occasionally, when faculty mentors and their summer researchers expressed interest in continuing their research projects during the academic year, accommodations were made to enable remote access. For example, a chemistry faculty mentor and his undergraduate research team wrote a successful grant application to acquire additional observation time on the Green Bank Telescope (GBT). This resulted in one summer research program alumnus receiving GBT training and the opportunity to conduct astronomical observations. In addition, during the academic year this faculty mentor engaged a team of undergraduates, graduate students, faculty, and National Radio Astronomy Observatory scientists in publishing the discovery of cyanomethanimine in *The Astrophysical Journal Letters* (Zaleski et al., 2013). This collaborative publication process increased the students' subject matter expertise and enhanced their STEM identity.

## Conclusion

Through reflections on our program design and assessment, we identified essential elements for a summer research experience designed primarily for underrepresented students at a PWI. We then presented lessons learned framed as challenges and recommendations to address the needs of students from varied backgrounds and home institutions. We learned that collaboration, multi-tiered mentoring, and faculty training are critical to a successful undergraduate research program. In addition, students benefit most from summer research programs when they include community building, professional development opportunities, and an overview of the graduate school admissions process.

Through the alumni survey results, the research team gained knowledge about students' education outcomes and career trajectories. The VA–NC Alliance Summer Research Program resulted in significant outcomes including additional research experiences, graduate school enrollment, degrees earned, and STEM employment. With 100% retention of summer researchers, 67% of survey respondents obtained additional research opportunities, 93% planned to work in a STEM field, and 27% either enrolled in a STEM graduate program or earned a STEM graduate degree. As discussed in the analysis of the survey results, demographic differences were observed in the respondents' answers to survey questions; however, due to the small sample size, these differences were not statistically significant. We observed the following: 1) Twice as many women responded to the survey than men; 2) slightly more women than men secured undergraduate research experiences (70% versus 66%); and 3) marginally more women planned to work in a STEM field (95% versus 88%).

Future study will allow for more in-depth analysis, using additional survey instruments and an expanded data set, examining group differences, and exploring trends revealed by the results. A significant percentage of the program's alumni were first- and second-year students, still enrolled in their undergraduate programs at the time of the survey – therefore, additional time will be needed to track their professional outcomes. It is the intention of the authors to survey the alumni at regular intervals to compare data over time, including cohorts who have participated in the summer research program since the time of the initial survey. We plan to disaggregate students by the classification at time of participation to calculate an average time to degree and graduate school acceptance and/or entrance to the workforce. Additionally, the authors plan to incorporate a control group in the next stage of this research. Outcomes from a control group of students in LSAMP who did not participate in the summer program

would inform program evaluation with quantitative results, comparing the percentage of participants obtaining additional research opportunities and other academic and career outcomes to the percentage of non-participants who obtained these outcomes. In addition, the next stage of program assessment will include analysis of pre- and post-survey data from summer researchers, using Bloom's Taxonomy to describe their progress. Furthermore, the authors plan to compare the progress of students who participated in the summer program's elective activities to those who solely engaged in the required events. Going forward, the authors plan to use the survey instrument developed and validated by Byars-Winston et al. (2016) to compare academic and career attainment outcomes, particularly student persistence in STEM, between summer research program participants and the control group. The authors plan to write the results of this further study in a subsequent paper. Additional research drawing on national data sets pertaining to STEM research, graduate program enrollment and degree attainment, and employment is needed to assess the impact of gender and other demographic differences on outcomes. Future study and an expanded data set would allow researchers to examine the impact of intersectionality on students' summer program experiences, self-efficacy, sense of belonging, graduate school and career trajectories, and STEM identity.

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**Kristin L. Morgan** serves as Senior Director for Grants Administration and Strategic Partnerships in the Office for Diversity, Equity, and Inclusion at the University of Virginia (UVA). She is the Co-Principal Investigator and Program Director for the Virginia–North Carolina Louis Stokes Alliance for Minority Participation (VA–NC Alliance), funded by the National Science Foundation. As part of her broadening participation efforts, Kristin co-founded the VA–NC Alliance Undergraduate Summer Research Program and researches the impacts of STEM intervention programs on underrepresented students. She received her B.A. in Religious Studies from UVA and M.A. in Applied Anthropology from Oregon State University.

**Dr. Jasmine Crenshaw** is the Director of Diversity Programs, Office of Graduate and Postdoctoral Affairs at the University of Virginia. She received her B.S. in Physics from North Carolina A&T State University and M.S. and Ph.D. degrees in Materials Science and Engineering from the University of Florida. She works collaboratively to establish academic and professional development programs, cultivating a supportive environment for graduate students and postdoctoral scholars. Dr. Crenshaw is keenly aware of the value and need for academic support initiatives and works to broaden participation in STEM through the Virginia–North Carolina Louis Stokes Alliance for Minority Participation.

**Dr Marcus L. Martin** is Professor Emeritus and past Chair of the Department of Emergency Medicine as well as former Vice President and Chief Officer for Diversity and Equity at the University of Virginia. After earning bachelor's degrees in Pulp and Paper Technology and Chemical Engineering from North Carolina State University, Dr. Martin became a member of the charter class of Eastern Virginia Medical School and was the first African American graduate to earn his medical degree there. In addition, he served as the Principal Investigator of the National Science Foundation-funded Virginia–North Carolina Alliance for Minority Participation.