

Cultivating Success through Undergraduate Research Experience in a Historically Black College and University

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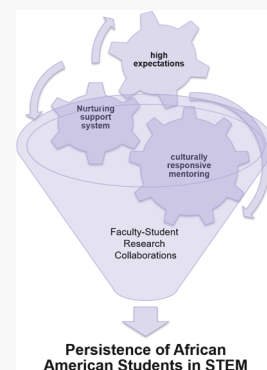
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ABSTRACT: This reflective overview describes the benefits of participation in authentic undergraduate research for students at a Historically Black College and University (HBCU). The department of chemistry and biochemistry at Hampton University has an undergraduate research environment that empowers and fosters a success-oriented research experience for our diverse students. By engaging undergraduate students in research early in their careers, we successfully motivate students to make informed decisions about pursuing STEM careers and entering graduate schools with high confidence. Our structured undergraduate research experiences are created within an inclusive environment that instills a sense of belonging and recognizes the talent all our students bring to STEM. We reflect on our experiences using faculty–student research collaborations within nurturing support systems that leverage African American culture while setting high expectations to improve scientific skills and retain our HBCU students in STEM.

KEYWORDS: Curriculum, Collaborative/Cooperative Learning, General Public, First-Year Undergraduate/General, Second-Year Undergraduate, Upper-Division Undergraduate



INTRODUCTION

The science, technology, engineering, and mathematics (STEM) workforce does not reflect the racial, ethnic, socioeconomic, and makeup of the United States of America.^{1,2} Despite interventions by government, industry, and academia, the relative percentage of African Americans graduating with STEM degrees and entering the workforce has remained low.^{2–7} Some studies suggest lack of interest as one of the main reasons for the low STEM participation of African American and other historically marginalized students.^{8,9} However, many of these studies assume that students have equal opportunities to succeed in STEM and ignore the persistent opportunity gaps. Even under the right circumstance, once underrepresented students embark on STEM career training pathways, they often encounter numerous obstacles: stereotypes, racism, microaggression, and lack of support for diverse research interests.^{8–10} Additionally, these studies fail to acknowledge the various pathways that students take to earn STEM degrees.^{11,12}

An increasing number of historically marginalized students are studying and thriving in STEM fields, mainly due to the current efforts to retain marginalized students in STEM. Historically Black Colleges and Universities (HBCUs) and Minority Serving Institutions (MSIs) play a major role in preparing many African American students in STEM. Despite enrolling only 8.5% of all African American students, HBCUs consistently award almost 18% of all STEM degrees.¹³ Furthermore, 21 HBCUs are among the top 50 institutions

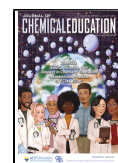
for producing African American graduates who go on to receive their PhDs. in STEM fields.^{14,15} While non-HBCUs or MSIs with black enrollment larger than most HBCUs are devoted to broadening the participation of minorities, some of the key factors that contribute to the success of HBCUs include the following: (1) more one-on-one contact with undergraduate students which can instill positive outcomes in STEM; (2) supportive environments committed to excellence both inside and outside of the classroom that provide the tools needed to instill and cultivate character, confidence, and intellectual curiosity; (3) presence of a large number of black faculty members who understand black culture and are more supportive;¹⁶ (4) the mission of HBCUs prioritizing the collective success over the individual. This minimizes the feeling of isolation and invisibility encountered by underrepresented students. In their mission, HBCUs have policies and practices to accommodate and advance the success of STEM students who have less academic preparation and resources. For a chemistry and biochemistry department that only averages ~55 undergraduates per year, we produce on

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average nine biochemistry and chemistry BS degrees every year. Figure 1 shows the number of biochemistry and

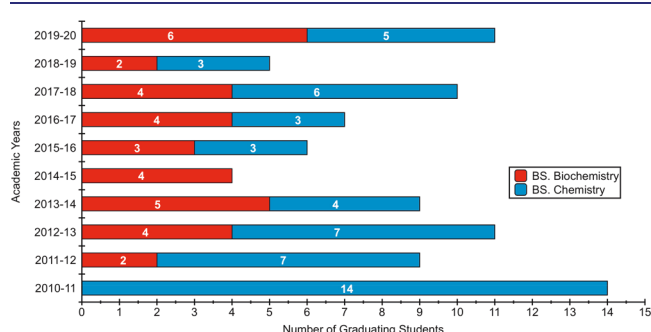


Figure 1. Number of biochemistry and chemistry BS degrees awarded at HU from 2010 to 2020.

chemistry BS degrees awarded at Hampton University from 2010 (14 graduates) to 2020 (11 graduates). At Hampton, we have three degree options within the undergraduate program: BS in Chemistry, BS in Biochemistry, and BS in Chemistry with a concentration in Forensic Chemistry.

Like many HBCUs, a commitment to excellence has been part of Hampton University since its inception over 150 years ago. Hampton University is a comprehensive institution of higher education dedicated to promoting learning, building character, and preparing students for research, leadership, and service careers. Of the nearly 5000 total students enrolled in the 2019–2020 academic year, 91% were African Americans, and females constitute 66% of all students. Despite our enrollment level, Hampton University consistently ranks in the top 50 institutions for African American graduates who receive STEM PhDs. Beyond the classroom, specifically STEM research, experiential learning has played an essential role in engaging our students in STEM. The experiential learning activities are hands-on laboratory experiments, mentored undergraduate research, and internships. Students gain personal and professional benefits, including increased self-confidence, independence, readiness for the following college level, and enhanced critical thinking skills from undergraduate research experiences.^{17–21} Our engagement of students in research activities include best practices that HBCUs use to enhance the students' success and persistence in STEM. These best practices include cultivating nurturing support systems, leveraging African American culture and identity, and setting high expectations.²² Later, we reflect on how some faculty members in the chemistry and biochemistry department at Hampton University use inspiring, conducive, and inclusive faculty-led mentored research activities to improve STEM success and retention. This is then employed with the implementation and outcomes of these best practices that are shared among HBCUs to address the issues of diversity, equity, inclusion, and respect as part of ongoing challenges and successes in retaining students in STEM.

■ CULTIVATING NURTURING SUPPORT SYSTEMS

Hampton University is a private university, and our students have a wide range of economic backgrounds and different levels of STEM preparedness. Many are first-generation college students.²³ Instilling a sense of belonging, instilling academic exceptionality, curbing imposter syndrome, and creating an empowering environment that recognizes their academic

potential and talent are the department's goals. We achieve these goals by nurturing support systems in small classrooms and developing strong student cohorts through scholarship, mentorship, and research. We employ culturally relevant pedagogy (CRP) which can be divided into five dimensions as shown in Figure 2.²⁴ In our department, we embrace CRP

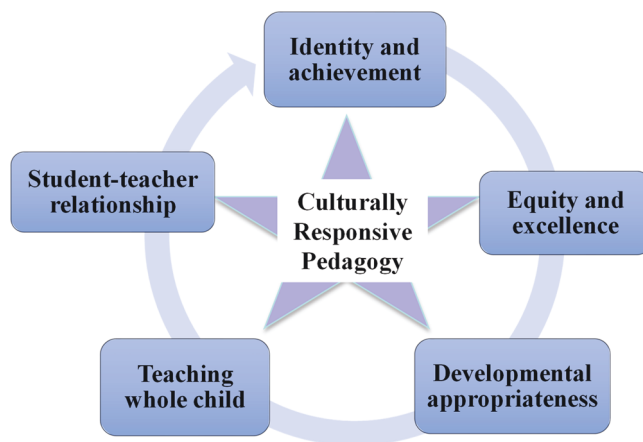


Figure 2. Graphical summary of the key dimensions in culturally responsive pedagogy that have been employed in the department of chemistry and biochemistry at Hampton University to create an inclusive environment that recognizes the talent all our undergraduate students bring to STEM.

through identity development and a high expectation for all, employing various teaching styles that recognize that students are individuals who could benefit from different learning experiences and teaching approaches, and a supportive learning community that creates a positive teacher–student relationship and builds a caring learning atmosphere.

We have used different teaching techniques to move students from a passive learning model to an active learning model in our teaching methods. This involves incorporating different teaching strategies such as Process Oriented Guided Inquiry Learning (POGIL), Student-Centered Active Learning Environment for Undergraduate Programs (SCALE-UP), Course-Based Undergraduate Research Experiences (CURES), and Discovery Based Computational Educational Experiences. The department has a long tradition of having monthly departmental meetings for all majors, nonmajors, and faculty where students can raise questions or bring to the attention of faculty what problems they may have that needs to be addressed. Those meetings continued remotely during the COVID-19 pandemic.

Beyond the classroom and lab, we hold an annual departmental dinner where chemistry majors are invited to share a delicious meal prepared by staff and faculty. Certificates of recognition are awarded to chemistry majors with outstanding academic performances in general, organic, and physical chemistry. Furthermore, students give research presentations that are followed by presentations from department alumni. Moreover, during the pandemic chemistry faculty scheduled Zoom meetings with students outside of their office hours to counsel students in both group and individual sessions. This allowed students to build a sense of community within their class and major. As it relates to the curriculum, cultural identity was reinforced to incorporate whenever possible chemical innovations, achievements, and awards of

Table 1. Active STEM Pipeline Programs at Hampton University

	HU-CHEM	STEM Scholars	PREM	LS-AMPS	Ronald McNair	NIH/NIGMS	MARC/U-RISE
Funding Entity	NIGMS	DOD	NSF	NSF	Department of Education	NIH/NIGMS	
Lead	HU	HU	HU-Brandeis	Howard	HU	HU	
Funding dates	2020–2023	2018–2023	2018–2024	2018–2023	2017–2022	2013–2025	
Who is eligible to participate in the program	First-year STEM students in CHE 201	Incoming 2018 merit scholarship recipients who have taken a diagnostic test	Rising sophomores, masters students, and postdocs	First Semester sophomore	Juniors and Seniors; 66% low income; 33% URM	Juniors and Seniors who want to pursue a PhD or MD/PhD	
Major eligible to participate	STEM	School of Science	All STEM majors, but mainly engineering	STEM	Any	Biology, biochem, math, chemical engineering	
Research training in the program	N/A for SCALE-UP, CUREs is a research-based	Year-long and external summer internships	Year-round and summer REU	Year-long and external summer internships	Year-long and external summer internships	Year-long and external summer internships	
Courses developed for the program	Curriculum updates to CHE 201, SCALE-UP, CUREs	None	Materials minor to be developed	None	None	Bio 311 and Bio 312; RCR, research methods	
Seminars in the program	Faculty development workshops	Dean's seminar series	None to date	None	None	Pathway to PhD; Bio 425 seminar; RCR; journal club	
Number of students participating yearly	At least 75 in 3 interventions	17 freshmen from 2018 year only	8 undergrads/2 Masters/2 postdocs	5 undergrads	25 undergrad and graduate	6 juniors and seniors	
Minimum GPA	N/A	Merit Scholar GPA; maintain a 3.3	3.0	3	3.0	3.2	
Funds provided to participants	Research funds for research boot camps	Scholarship; Room and Board	Stipends for students/wages for postdocs	Stipend and travel support	Stipends and research support	Tuition scholarship; stipend; travel	
Outcomes measured	Persistence in STEM and all outcomes from McNair and MARC/URISE	No. of students that apply and matriculate in PhD or MD/PhD programs; DOD workforce	No. of students who pursue careers in materials engineering/science	No. of students that apply and matriculate in the PhD program	Percent of students completing research and scholarly activities; percent of students accepted and enrolled in postbaccalaureate programs or attaining PhD in 10 years	No. of students that apply and matriculate in PhD or MD/PhD programs; no. of students that apply and matriculate in masters or PREP programs	

African American chemists. This was accomplished through guest speakers, seminars, writing assignments, and group presentations. For some students, this was their first exposure to black excellence in STEM which served as a vehicle to encourage their retention in the major.

Many first-year students arrive at Hampton University unaware of 21st century STEM career opportunities. As a service department, faculty members in the chemistry and biochemistry department teach first-year STEM and non-STEM majors' general chemistry. The enrolled students have different economic backgrounds, different levels of college preparedness, and different levels of interest and motivation in majoring in STEM fields. More importantly, despite the high levels of interest and motivation, many of these students come with limited knowledge of the multitude of STEM educational and professional opportunities. In addition, freshman students are encouraged to participate in a peer-to-peer mentorship with upper-level classmates within the department. Faculty members engage with students to encourage their participation. The chemistry classes provide an opportunity to engage students in intramural STEM research and work with our faculty colleagues across the Hampton University campus to inform students about various career-enhancing programs. Our robust multidisciplinary research environment at Hampton includes cohort-building multiyear scholarship programs (Table 1). In addition, faculty routinely involve students in their grant- and foundation-funded research programs like the Hampton-Brandeis Partnership for Research and Education in Materials (PREM-NSF), National Institute of Health Minority Access to Research Careers (MARC-NIH), Nanoscience: Transforming STEM Education at Hampton University an HBCU Undergraduate Program Excellence (ACE) Implementation Project (HBCU-UP ACE NSF), Centers of Research Excellence in Science and Technology (CREST-NSF), and American Chemical Society Petroleum Research Fund for Undergraduate Research (ACS PRF UR), which provides interdisciplinary research experiences for STEM undergraduates (Table 1). The authors of this paper serve as principal investigators (PIs), coprincipal investigators (Co-PIs), or senior personnel in all of the listed pipeline programs (Table 1). Despite our success, our 10-year data analysis revealed ~50% attrition of first-year STEM majors which is consistent with the national average. To remedy this, the Chemistry and Biochemistry Department is currently implementing a National Institute of General Medical Sciences (NIGMS) funded U01 program (HU-ChEM) to engage faculty and students and scale up efforts to develop more significant nurturing supportive STEM ecosystems starting with students in general chemistry.

The faculty who are teaching gatekeeper chemistry courses are trained in cultural responsiveness through workshops with subject matter experts. Through these trainings, we are able to leverage our African American culture and identity in teaching.

In the words of James Baldwin, "A child cannot be taught by anyone who despises him, and a child cannot afford to be fooled. A child cannot be taught by anyone whose demand, essentially, is that the child repudiate his experience and all that gives him sustenance."²⁵ Faculty and teachers at Hampton University are diverse with intersectional identities. Thus, we can relate to our students and recognize the value of their lived experiences. A study on underrepresentation of minority students in STEM by Slovacek et al. states, "For minority students whose mentor is also a minority, that relationship can

serve as a powerful reminder that the prevailing stereotypes of minorities in the sciences can be overcome."²⁶ The reflection from a former student and now a faculty member explains the importance of leveraging African American Culture and Identity. Our ability to leverage our students' lived identity is referred to as cultural responsiveness. Culturally responsive educators do not serve as gatekeepers to STEM persistence. Instead, culturally responsive educators actively recognize and foster the persistence of diverse students in STEM.^{27–29} Our practical approach as culturally responsive educators is to design curricula and pedagogy that meet our students' cultural and motivational needs while retaining academic rigor.

Furthermore, culturally responsive pedagogy requires awareness of biases and developing evidence-based approaches to mitigate them. We meet the students where they are and respect them and their diverse African American cultural identity. We incorporate examples of African American chemists in our classes and use our personal and professional experience to emphasize inclusive excellence. Over the past three years, the administration at Hampton University has provided faculty training institutes to enhance cultural responsiveness, especially the generation-gap challenges. Additionally, as a department, we actively engage in faculty workshops that provide formal training in cultural responsiveness as part of HU-ChEM. The impact of shared cultural experiences and psychological benefits of being exposed to highly educated African American faculty helps reinforce the use of a culturally responsive pedagogical approach to foster our STEM students' academic success.

Importance of Setting High Expectations

Of the 21 HBCUs on the NSF's top 50 lists, Hampton University is ranked fourth for graduating students who earn STEM PhD degrees.^{14,15} The department of chemistry and biochemistry at Hampton University produces ACS certified BS degree holders in chemistry and biochemistry who go on to obtain STEM PhDs and professional degrees. A key to our success is the high expectations that we set during our intramural research experiences in the laboratories of faculty-scholars committed to providing mentorship and a supportive learning environment.¹⁶ For example, the faculty within the department have mentored students during their undergraduate tenure at Hampton University through individual meetings which assess their academic and career trajectory, counselling following internship experiences and inclusion in research experiences in person and online. In addition, during their freshman year, each student has several meetings with the department's chairperson to develop their individual plan for academic success (Student I-PASS) in consultation with the Hampton University's student success center. This Student I-PASS is designed to serve as a guide for students to achieve their desired career aspirations.

Furthermore, students get fully engaged conducting research under the guidance of a faculty where they are expected to publish their research in peer-reviewed articles and present at scientific conferences. We use high expectations within research to prepare students for their next career stage and become life-long independent learners. Students participating in research activities gain real-world scientific skills and the tools needed to instill and cultivate their confidence and intellectual curiosity. Additionally, maintaining robust research programs enhances our faculty's teaching and relevance to serve as positive, aspirational role models for students

interested in doctoral-level degrees and STEM careers. In this respect, all of the authors mentor undergraduates in their research laboratories.

Our department has research courses for all undergraduate academic levels, from the first year to the senior level. Each research course has a structured syllabus that includes the learning objectives, research focus, and assessment methods (Table 2). Each course has high expectations that students and their faculty mentors must achieve (Table 2).

In 2020, we redesigned the biochemistry curriculum to include mandatory research experiences for our students. Furthermore, research courses count as electives toward the student's course requirements for graduation. Approaching the undergraduate research experience as a structured course with high expectations enables students to know what they are committing to in these courses. Another benefit of our structured faculty-led mentored research experiences is that the course level has specific learning objectives focused on fostering students' progress and growth as scientists.

Our approach allows us to integrate research activities into the broad laboratory curriculum, which in turn helps in strengthening the research-teaching endeavors in the department. This sequence of sustained course-based undergraduate research has been maintained for more than 20 years. We can engage more students by using peer-mentors in the research projects where our more experienced student researchers help other students. As a result of research experiences, students have additional time for face-to-face interaction with their faculty mentors to discuss academics and social-cultural issues. Additionally, students get the opportunity to design and implement independent research projects that they can implement under the guidance of one or more faculty mentors. Students also gain research mentors and advocates that know them well enough to write the support letters required for the next stage of their STEM careers. Our research activities are not limited to our majors, and we routinely engage students from other departments, some of whom take our research classes as electives. Consequently, students are exposed to a variety of scientific career pathways. Students are more likely to pursue scientific careers when they are exposed to research experiences.

While ~44% of our majors have matriculated into STEM graduate programs (Figure 3), ~75% of students engaged in research went on to STEM graduate programs. Impressively, a substantial number have completed their graduate studies successfully. There were 20 students who participated in research activities throughout their undergraduate studies, while 10 students have done so partially. The success of our students reflects the importance of engaging undergraduates in research.

We have learned that early and continuous participation in undergraduate research helps retain students in STEM. Students who participated in undergraduate research in our laboratories had higher grades, retention, and a higher likelihood of graduating within four years. Other benefits for participating students include enhanced learning due to the mentor/mentee relationship with faculty, development of critical thinking and problem-solving skills, and intellectual independence. Faculty engaged in active research collaborations with students incorporated the lessons learned in their classroom and tended to be more effective instructors of modern relevant STEM training.

Table 2. Hampton University Department of Chemistry and Biochemistry Research Courses

Course Number	Title	Course Description
CHE 114	Introduction to Research Topics in Chemistry	Designed for freshman-level undergraduates. Emphasis will be placed upon introduction to areas of chemistry research, regular attendance at appropriate seminars, techniques of literature searches, and background study. This course may be taken twice. Prerequisite: Consent of the department chairperson. Seminar/Project/Credit 1–6.
CHE 214	Basic Research Topics in Chemistry	Designed for sophomore-level undergraduates. Emphasis will be placed upon introduction to basic techniques of conducting research and literature review, regular attendance at selected seminars, and directed work on a research project in chemistry. This course may be taken twice. Prerequisite: Consent of the research mentor. Seminar/Project/Credit 1–6.
CHE 314–315	Introduction to Chemical Research	A two-semester course sequence designed to provide chemical research initiation and enrichment for junior chemistry and biochemistry majors. Emphasis is placed on the orientation of students to the general and specific objectives of research and to the use of research tools and techniques. Students will perform entry-level research under close supervision. Prerequisite: Consent of chairperson. Project/Credit 3.
CHE 414–415	Chemical Research Applications	A two-semester research course sequence for senior chemistry majors. The course offers a rigorous and comprehensive foundation in research fundamentals and techniques. Students who take one or both courses of the CHE 414–415 sequence must also write a research paper. Both CHE 414 and CHE 415 meet for a minimum of 6 h per week for 15 weeks. Project 3/Credit 3.

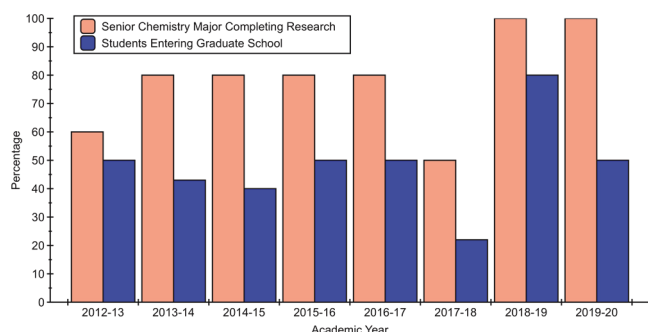


Figure 3. Number of biochemistry and chemistry undergraduate students who completed faculty-led research and entered graduate school from 2012/2013 to 2019/2020.

As observed by others in the STEM literature, our mentored undergraduate research also improved students' interest in pursuing STEM graduate programs.^{30,31} Our chemistry and biochemistry 2021 seniors exit survey shows that 45.5% of the students plan to attend graduate/professional school full-time. The same survey showed that 91% of the students derived great personal satisfaction from working on a team that was performing research. Moreover, undergraduate researchers in our laboratories are coauthors in five peer-reviewed publications.^{32–36} Undergraduate students who participated in research have all made presentations in at least one national, regional, and local conference. Furthermore, the research students have received 15 awards from poster competitions in a number of conferences, ACS scholar scholarships, and Hampton University Presidential awards at different times during their research experience. All of the students receiving these recognitions have gone on to enroll or complete graduate STEM programs. This contrasts with students that have not participated in research within the department or external summer research experiences. None (0%) of the students in this category have obtained advanced graduate or professional STEM degrees after graduation. The increases in STEM efficacy and success from high expectations and STEM research are subsequently discussed in our individual reflections.

FACULTY REFLECTIONS

In the following section, Dr. Waddell, Dr. Ghebreyessus, Dr. Njoki, and Dr. Ndip will discuss their professional experiences and research on their mentorship of African American undergraduate students in STEM careers. Dr. Asojo will highlight her engagement of students in computational research during the COVID-19 shutdown. Each faculty mentor will give their unique perspective on their strategy for guiding student success through research experiences. Specifically, we highlight the experiences of Dr. Waddell, a Hampton alumna and current faculty member who actively engages students in research and mentorship. These reflections reinforce what has been reported in the book "Seeing The Hidden Minority: Increasing the Talent Pool through Identity, Socialization, and Mentoring Constructs". Thus, "When Black STEM students at HBCUs are able to have a mentor that is also a member of an underrepresented population, this can serve to increase a mentee's self-efficacy. This increase in self-efficacy is due to a mentee seeing that he or she can achieve a desired set of goals because their mentor is proof of this possibility."³⁷

From Hampton Student to Faculty (Dr. Waddell)

Coming from a blue-collar steel worker union household, Dr. Waddell was a product of a public education system in a predominantly African American city. Although enrolled in the gifted and talented program, Dr. Waddell was not completely prepared to enter college as a chemistry major. Unfortunately, like undergraduate students today, Dr. Waddell was not aware of the deficiencies in her college preparatory education. At her school within the curriculum, the highest level of math in the gifted and talented program was precalculus. Only students who planned to major in engineering were offered the limited number of calculus classes. The only high school hands-on laboratory experience was freshmen biology when the students dissected several animals. In four years of high school science, Dr. Waddell took biology, chemistry, physics, advanced biology, and advanced chemistry. Advanced Placement (AP) credited science courses were not offered, and three out of four years highlighted instructor demonstrations. Consequently, she was not engaged in recording data, results, and observations. In her first year at Hampton, as a chemistry major, she learned how deficient her high school was through exposure to other students and the high expectations of her chemistry professors. Over the course of her four years at Hampton University, Dr. Waddell was guided and challenged to the highest level of achievement despite deficiencies in her high school training. A significant portion of her intellectual growth occurred through research experiences. During her entire undergraduate career, she participated in both summer and academic-year research with chemistry faculty. Her learning experience outside the classroom was extremely beneficial and motivated her to visualize life as a scientific researcher. While the classroom incorporated foundational knowledge, academic and industrial research allowed exposure to potential careers beyond college.

Dr. Waddell's philosophy when mentoring undergraduate research students involves building their technical competence, improving writing skills, instilling confidence, and developing critical thinking skills. She takes an approach of encouraging her students to understand and apply their learning to new scenarios. She also guides students to use their foundational knowledge to solve problems. She strongly believes that research is the best way to help nurture science identity, gain confidence, and overcome a fear of failure. She trains her students that failure is an essential part of research and must be embraced as a part of the research process. Dr. Waddell has mentored a total of 15 students through her research group at Hampton University. One of her research mentees is a 2018 recipient of the National Science Foundation Graduate Research Fellowship (NSF-GRF). One student has earned a PhD, one has earned an MD, three students have earned master's degrees in the sciences, and four students are current degree candidates in graduate or professional school programs (pharmacy, physical therapy, and medical school). Students in her group have presented their research results at the Virginia Academy of Sciences, the National Organization of Black Chemist and Chemical Engineers, the Annual Biomedical Research Conference for Minority Students conferences, Louis Stokes Alliance for Minority Participation-Washington Baltimore Hampton Roads conference, and Society for Neuroscience Conference. More than half of the students she has worked with have been accepted and matriculated to graduate science degree programs. In fact, due to the interdisciplinary aspects of her research, a full third of the students working in her research lab were biological science majors. Through her

experience as an undergraduate at Hampton University, she has been successful in guiding students through research. This has contributed to the overall success of the undergraduate research and mentorship program within the department.

Engaging Undergraduates with Inorganic Chemistry (Dr. Ghebreyessus)

Dr. Ghebreyessus' research focuses on the design and synthesis of novel photoresponsive inorganic/organometallic materials that can be used to address biomedical, energy-related, and nanotechnology-related challenges. Students who join Dr. Ghebreyessus's lab are engaged in research activities that involve chemical synthetic methodology to prepare organic, organometallic, and inorganic compounds. These research activities also incorporate significant hands-on experiences with chemical instrumentation, which are critical to succeeding in graduate school and other career goals.

Since joining Hampton University, Dr. Ghebreyessus has mentored over 25 undergraduates in these research activities. When mentoring students, Dr. Ghebreyessus believes that one of the most effective techniques to prepare students for a career in the sciences is to become a scientist by doing what scientists do. Hence, the students working in Dr. Ghebreyessus' lab are fully engaged in the research efforts, from reading pertinent literature materials to performing the actual experiments, and presenting their research findings at ACS national and regional meetings and coauthor publications. Many of these undergraduates have successfully completed their PhD studies in STEM fields, and some are still in graduate school. Participation in an engaging undergraduate research experience has played a pivotal role in the success these students enjoyed in graduate school. Additionally, some of the students have won awards including the prestigious NSF GRF and ACS scholars.

Using Materials Science Research to Engage K–12 and Undergraduate Students in STEM (Dr. Njoki)

As indicated by my colleagues, the involvement of undergraduates in research experiences influences the students' confidence and identity as chemists.³⁸ Furthermore, studies show that early involvement of underrepresented minorities in research fosters students interest and competency in STEM subjects and research.^{39,40} Dr. Njoki's engagement of students through faculty research and mentorship has led to 6 underrepresented high school students^{32,41} and 10 undergraduates getting interested in chemistry⁴¹ and participating in materials science research.^{42,43} The high school students were introduced, engaged, and mentored in nanoscience research in a six-week summer program that culminated with a poster session. Over 60% of the high school mentees have since joined college where they are pursuing STEM studies and coursework.^{34,41,43} One of the mentees joined Hampton University in Fall 2019 as a chemistry major and continued to work in my lab with the support from an ACS PRF UR grant. The student became a coauthor in one of our publications while still a freshman.³⁴

The undergraduate students are engaged in different facets of materials science research that involves synthesis and characterization of nanomaterials that have applications in renewal energy, catalysis, and forensic analysis. Additionally, students investigate the environmental impacts of the vast applications of nanomaterials in consumer products. Moreover, the students in Dr. Njoki's lab are involved in data processing using a variety of software and are coauthors in peer-reviewed

journals.^{32–34} The students get experience in manuscript preparation through data processing, literature review, and writing.

Moreover, the students presented their work at scientific conferences, namely, the Virginia Academy of Science, National Institute of Science and Beta Kappa Chi, National Organization for the Professional Advancement of Black Chemists and Chemical Engineers (NOBCChE), Emerging Researchers National (ERN) Conference in STEM, and American Chemical Society. The research and presentation experiences led to the students building remarkable resumes that culminated in academic scholarships for undergraduate studies and graduate school. Dr. Njoki serves as the PI of ACS PRF UR, one of the three PIs of the URISE program, and coinvestigator of HU-ChEM. One of the goals of the ACS PRF UR grant is to "develop the next generation of engineers and scientists through support of advanced scientific education."⁴⁴ One of the aims of the U01 grant is to use course-based undergraduate research experiences to retain first-year students in STEM.

Engaging Learners (K–12 and Undergraduates) with Computational Science (Dr. Ndip)

Dr. Edmund M. Ndip is a past recipient of the Edward L. Hamm, Sr. Distinguished Teaching Award with over 25 years of service at Hampton University. K–12 and undergraduates (over 40) engaging in research under Dr. Ndip's guidance receive experiential training in the applications of computational chemistry to problems in chemistry (molecular and electronic structure and property calculations, elucidation of organic reaction mechanisms, structure–activity relationships in natural products and other compounds with significant medicinal and biological activities), and materials science (structure–property relationships in multichromophoric systems, materials for imaging and electronics). The challenges for instruction and research using quantum mechanics and spectroscopy include the abstract and nonintuitive nature of many concepts often requiring higher order mathematical skills.⁴⁵ Students develop skills to overcome these challenges through a combination of computation and visualization techniques (computational science). K–12 students and undergraduates use *ab initio* and semiempirical methods to study the electronic and molecular properties of a broad spectrum of organic and inorganic materials. Overall, projects are interdisciplinary involving computation, a wide range of synthetic methodology, and spectroscopic techniques.

For this author, mentoring means helping the student participant to develop the ability to relate textbook knowledge to applications (technical competence), development of skills in all aspects of the research enterprise (project development, development of a plan of work, and execution and communication of experimental results through the preparation of reports, presentations, and papers),⁴⁶ self-reliance, and an ability to be an effective member of a team. The notion that everyone is capable is stressed. This author works with each student participant on each step of the process until confidence is gained. The student is then empowered to execute the project pursuing whatever angle most interests the student. Over 90% of mentees in this lab have gone on to earn advanced degrees in STEM (MS, PhD) and health and allied health professions (MD, PharmD, DDS) leading to positions in academia and industry. The modeling lab participates in collaborative research efforts with most of the authors to

provide enhanced research experiences for undergraduate students.

RESEARCH ACTIVITIES DURING COVID-19

Coronavirus disease 2019 (COVID-19) disrupted the research activities when students went home for remote instructions when our university closed.⁴⁷ This meant no in-person training or wet-lab research activity could take place. We handled this setback by concentrating on data processing of the results data prior to COVID-19 disruption and computational research. In addition, the students were trained in literature search and review from credible scientific sites, presentation of literature articles via Zoom videoconferencing during weekly meetings, presentation at virtual scientific conferences, and manuscript preparation. Interestingly, COVID-19 enhanced the research activities in Dr. Asojo's group, and she was able to engage more students and has several manuscripts in preparation on work conducted during the shutdown.

Engaging Students with Macromolecular Crystallography During COVID-19 (Dr. Oluwatoyin Asojo)

Dr. Asojo joined Hampton University in August 2018 after leading research programs at medical schools for over 16 years. Her objectives at Hampton include fostering scientific literacy and competency using active learning and research experiences. The Asojo laboratory uses X-ray crystallography and related approaches to study the chemistry of life processes. The research objectives of undergraduate research in the Asojo laboratory are to generate, interpret, or communicate new structural data while training participants in the fundamentals of the chemistry of life processes. Dr. Asojo's training philosophy is "that what you come with matters less than what you leave with." The research projects in the Asojo lab include hypothesis-driven research, science communication research, and discovery-based research. Dr. Asojo has mentored diverse undergraduates and K–12 students in STEM research since 1993. She remains impressed by the students' capability and competence when they are engaged and interested in STEM research.

Before COVID-19, students in the Asojo lab were engaged in "wet-lab" projects and learned aspects of modern biochemistry and molecular biology. Due to Dr. Asojo's high teaching load and administrative responsibilities as chair, from 2019 through 2020, Dr. Renata Baroni, a visiting postdoctoral fellow, supervised these labor-intensive projects. Due to space and equipment constraints, "wet-lab" research in the Asojo lab was limited to four undergraduate students per term and worked in shifts. With the shutdown in early Spring 2020, undergraduate researchers shifted their focus from protein production and crystallization experiments to structure interpretation, rational-drug discovery, and scientific communication.

There are no physical lab space constraints associated with computational research and science communication projects. By scheduling group sessions, Dr. Asojo trained multiple students remotely in the applications, software packages, and techniques they would apply to their unique projects. Dr. Asojo recorded the training sessions so students could practice and master approaches on their own. The students became well-versed and skilled. After a semester, students were helping to train their peers. Student groups are currently analyzing structural data from our collaborators at the Seattle Structural Genomics Center for Infectious Diseases (SSGICID). They will

submit their analysis as peer-reviewed structure report manuscripts. There was a 6-fold growth of intramural undergraduate research in the Asojo lab. In the two-year period from August 2018 through May 2020, there were 10 undergraduate researchers in the Dr. Asojo laboratory. Post-COVID-19 shutdown, from August 2020 through April 2021, Dr. Asojo mentored 32 undergraduates and 1 high school student. Dr. Asojo also serves as the PI of HU-ChEM and one of the three PIs of the URIS program. One of the aims of the U01 grant is to use authentic course-based undergraduate research experiences to retain first-year students in STEM.

CONCLUSION

Our reflection illustrates how we currently utilize best practices to improve student success in STEM at the Department of Chemistry and Biochemistry at Hampton University. Our preliminary analysis suggests that intramural research provided by culturally responsive mentors helps increase STEM persistence at Hampton University. We also provide examples during COVID-19 that allowed us to engage students in STEM research using the U01 grant to increase participation of first-year students in authentic research experiences. There are numerous challenges to scaling up these intramural research opportunities at Hampton University, such as financial constraints and high teaching loads. To increase success of our intramural research programs, there is a need for funding to support more students and provide personnel support.

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Notes

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