Cultivating PhD Aspirations during College

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ABSTRACT

Science, technology, engineering, and mathematics (STEM) career barriers persist for individuals from marginalized communities due to financial and educational inequality, unconscious bias, and other disadvantaging factors. To evaluate differences in plans and interests between historically underrepresented (UR) and well-represented (WR) groups, we surveyed more than 3000 undergraduates enrolled in chemistry courses. Survey responses showed all groups arrived on campus with similar interests in learning more about science research. Over the 4 years of college, WR students maintained their interest levels, but UR students did not, creating a widening gap between the groups. Without intervention, UR students participated in lab research at lower rates than their WR peers. A case study pilot program, Biosciences Collaborative for Research Engagement (BioCoRE), encouraged STEM research exploration by undergraduates from marginalized communities. BioCoRE provided mentoring and programming that increased community cohesion and cultivated students' intrinsic scientific mindsets. Our data showed that there was no statistical significant difference between BioCoRE WR and UR students when surveyed about plans for a medical profession, graduate school, and laboratory scientific research. In addition, BioCoRE participants reported higher levels of confidence in conducting research than non-BioCoRE Scholars. We now have the highest annual number of UR students moving into PhD programs in our institution's history.

INTRODUCTION

We developed a program that takes a multifaceted and vertically integrated approach to encourage inquisitive and talented young scientists to view a PhD in the biosciences as an exciting, viable, and desirable option. The Biosciences Collaborative for Research Engagement Program (BioCoRE) executes a series of enrichment activities, mentoring programs, professional development opportunities, academic development workshops, and cohort formation activities for talented and diverse undergraduates and graduate students in biomedical and behavioral sciences at Duke. In this study, we compare and contrast the experiences in science, technology, engineering, and mathematics (STEM) of various student demographic groups and focus on programmatic strategies to maintain interest in biomedical, biological, and behavioral science research at the undergraduate level, and we present outcomes specifically related to BioCoRE's undergraduate population relative to a comparison group.

The Underrepresentation Problem in a National Context

A major strength of the United States lies in its racial, cultural, religious, geographic, and political diversity of viewpoints. Diversity supports critical thought, innovation, and creativity (Page, 2007). Additionally, a workforce of diverse individuals better enables the broad exploration of ideas and research pathways and can lead to more effective research teams (Watkins *et al.*, 1993). When selecting a problem-solving

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team from a diverse population of intelligent individuals, a team of randomly selected (diverse) individuals consistently outperforms a more homogeneous team of "best-performing" individuals (Hong and Page, 2004). Maximizing diversity in science is important, because science is not a purely objective pursuit; rather, science is conducted by individuals with their unique and subjective vantage points (Hetherington, 1983). As summarized by Yong (2019), "The conclusions that scientists draw from their data, and the very questions they choose to ask, depend on their assumptions about the world, the culture in which they work, and the vocabulary they use." Although the benefits of diversity are well documented (Sugrue *et al.*, 1999; Page, 2007; Valantine and Collins, 2015), many STEM fields maintain a mostly homogeneous and therefore relatively unrepresentative workforce, especially at higher education levels and job ranks. Homogeneity stems from a historical and systemic inequality of access and opportunity (Asai and Bauerle, 2017) and may be sustained by an accompanying set of unproductive assumptions (Poodry and Asai, 2018). The current lack of diversity in science constitutes a loss of talent and critical contributions that might otherwise enrich the enterprise (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2011; Tabak and Collins, 2011).

The branches of academic science are mainly populated by white and Asian males, who are thus considered to be well represented (WR), with corresponding deficits in the representation of women and other racial and ethnic groups (Nelson and Brammer, 2010; National Science Board, 2018). A recent study across all academic disciplines found that "STEM postsecondary fields stand apart via the disproportionate exclusion of Black and [LatinX] youth" and that there is "evidence of persistent racial/ethnic inequality in STEM degree attainment not found in other fields" (Riegle-Crumb *et al.*, 2019, p. 133). As a result of this exclusion, U.S. citizens and permanent residents from Hispanic/Latino, African-American/Black, American Indian or Alaska Native, and Native Hawaiian or Other Pacific Islander backgrounds are all underrepresented (UR) in biomedical research careers (National Science Foundation [NSF], 2017). In 2014, the combined portion of the total U.S. population from these groups was 31%, but among PhD-earning scientists, the representation was under 12% (NSF, 2017). In the same year, individuals from these UR groups accounted for only 6% of assistant professors in medical school basic science departments (Gibbs *et al.*, 2016). Skewed representation is common to the faculty ranks across all STEM fields (e.g., in chemistry: see Nelson and Brammer, 2010). Research grant statistics provided by the National Institutes of Health (NIH) suggest that even those UR scientists who attain faculty status can face further disparities in funding decisions compared with white peers who have similar publication and training records (Ginther *et al.* 2011, 2016). These findings indicate that events at multiple points along a career trajectory can combine to prevent an individual belonging to a historically marginalized group from becoming a leader in a research field. Projecting into the future, Gibbs *et al.* (2016) used a conceptual system dynamic model to estimate that the UR talent pool would only increase to 13.8% by 2030 (less than half the representation of UR individuals in the U.S. population), while UR faculty assistant professors would only reach 5.9% by 2030 and 8.9% by 2080. Thus, without additional interventions, gross underrepresentation will continue for decades.

Given the shifting demographics of the U.S. population, it is critical that we increase the diversity of the biomedical workforce (Maton and Hrabowski, 2004; Maton *et al.*, 2012; Asai and Bauerle, 2017; National Academies of Sciences, Engineering, and Medicine, 2018). When comparing undergraduates with similar precollege backgrounds at the national level, students belonging to UR groups exit STEM disciplines at significantly higher rates than students from WR groups (Huang *et al.*, 2000; Hurtado *et al.*, 2010; Poodry and Asai, 2018). Seymour (1992) indicates that many talented students do not pursue scientific research careers for various psychological, personal, and institutional reasons. Other contributing factors include economic disparities, which can disproportionally impact UR students and those who are first-generation scientists (Terenzini *et al.*, 1996; Thayer, 2000) and a perceived misalignment between personal values and academic success (Gibbs and Griffin, 2013).

Combating Persistent Drivers of Underrepresentation to Increase the Flow of UR Students toward the PhD

Increasing the talent pool at the PhD level is considered essential for the United States to retain a position as a world leader in science, engineering, and technology (National Academies of Sciences, Engineering, and Medicine, 2018). Thus, several national funding agencies, such as the NIH and NSF, offer institutional student training and development grants at all levels via programs that aim to increase diversity and inclusion in the American science pipeline. These efforts have contributed to an increase in PhD scientists from UR groups by a factor of 9.3 between 1980 to 2013, as compared with a 2.6-fold increase in the number of PhD graduates from WR groups (white and Asian; Gibbs *et al.*, 2016). A major component of such programs aims to enhance opportunities for early research experiences, which have proven to be critical to sustained interest in research careers (Murray *et al.*, 2016). Undergraduate research experiences positively impact completion of STEM degrees (Nagada *et al.*, 1998; Bauer and Bennett, 2003; Barlow and Villarejo, 2004; Seymour *et al.*, 2004; Gilmer, 2007; Lopatto, 2007; Russell *et al.*, 2007; Carter *et al.*, 2009; Jones *et al.*, 2010; Espinosa, 2011; Graham *et al.*, 2013) and interest in postgraduate STEM educational opportunities (Lopatto, 2007; Russell *et al.*, 2007; Carter *et al.*, 2009; Junge *et al.*, 2010). To provide early research experiences, institutional programs often target summer opportunities to students who do not attend a research-intensive university during the regular academic year. For a review of the summer bridge program approach, please see Ashley *et al.* (2017).

In addition, given that UR students are much less likely to arrive on campus with prior laboratory research experiences when compared with their WR peers, another approach is to combine research pathways with communities of scholarship for students belonging to UR groups (Chang *et al.*, 2014). A prominent and successful program of this kind is the Meyerhoff Scholars Program at the University of Maryland Baltimore County (UMBC; Hrabowski and Maton, 1995; Maton *et al.*, 2000, 2012; Maton and Hrabowski, 2004; Stolle-McAllister *et al.*, 2011). UMBC was the only predominantly white institution in the top 10 list of baccalaureate-origin institutions of 2005–2014 African-American doctorate recipients in the natural sciences and engineering (Hrabowski and Henderson, 2017). The Meyerhoff model recruits the most academically prepared, high-achieving high school seniors from UR groups before matriculation and provides cohort-based, research-intensive experiences and professional development programs to ensure retention. The Meyerhoff Scholars Program also provides 4 years of financial support as a merit award, and this is a factor for degree completion (https://meyerhoff.umbc.edu/13-key-components). This approach has clear benefits and shows a convincing track record of success at UMBC and when replicated at other institutions (Domingo *et al.*, 2019), but it excludes students who do not realize that they have interest in scientific research until they matriculate into their 4-year undergraduate institutions. Moreover, there remains a dearth of programs targeting the undergraduate experience for students who may develop an interest during their undergraduate experience outside research experiences for undergraduates. Many first-year UR undergraduates select health professions career pathways because they are not aware of research career pathways. While there are nationally funded postbaccalaureate programs (PREP and B2D) that intervene to provide research experiences for UR students *after* they have their 4-year degrees, these all delay PhD program entry in order to rectify a lack of research acumen that could have been developed during the college experience.

Tailoring a Program to Our Institution: A Case Study

Duke University is listed in the top five nationally among predominantly white institutions graduating students from historically UR groups who receive an MD ("The Top Feeder Schools for Black Medical Students," 2013; Association of American Medical Colleges, 2017). However, Duke has historically been the baccalaureate-origin institution for a much smaller number of science doctorate recipients for the same student demographic. Matriculating first-year undergraduates often enter Duke with both strong interest in science and visions of health-related careers. As an illustration, at Duke, 80% of students in a freshman-level chemistry course agreed with the statement "I plan to attend a health-related professional school (medical, dental, vet, pharmacy, etc.)" (Canelas *et al.*, 2017). At the same time, 40% of students agreed with the statement "I plan to attend graduate school in the natural sciences" (Canelas *et al.*, 2017). Some of these students may envision MD/PhD programs in their futures, but it seems likely that many students conflate science and medicine. This idea fits with reported nationwide trends indicating that many students who enjoy science at the start of their college training pursue a pre-medical course of study (Barr *et al.*, 2010; Chang *et al.*, 2014).

If Duke University's faculty and administration hoped to help the United States in meeting the projected future demand for trained scientists (President's Council of Advisors on Science and Technology, 2012), then interventions geared toward student retention in science tracks at the undergraduate level were clearly needed. To this end, internal self-studies were initiated by both the Trinity College of Arts and Sciences Office of Assessment and the School of Medicine's basic science program administration. Analysis of STEM course work data collected from 2004 to 2009 revealed that UR undergraduates were underperforming in terms of grade achievement relative to their WR peers in General Chemistry 1, the first science class taken by most undergraduates at Duke University (the biology gateway course has a chemistry prerequisite at Duke; Trinity College Office of Assessment, 2009; Hall *et al.*, 2014). This disparity was troubling, because undergraduates who change their minds about career pathways often do so based upon their experiences in course work during the first 2 years (Seymour, 1992; Seymour and Hewitt, 1997). Creation of the Office of Biomedical Graduate Diversity at Duke University (DePass and Chubin, 2017) prompted another institutional self-study in 2011–2012. Major findings revealed that, although Duke benefits from a strong, well-prepared supply of matriculating undergraduate students from UR groups who express an interest in science, an average of just *one* person per year reported heading into a PhD program as their next position. Two factors were hypothesized to explain this phenomenon: 1) poor performance by UR students in first- and second-year science classes and 2) low levels of engagement of these students with the scientific community.

The first barrier, historically poor performance by UR students in foundational science classes, was addressed via departmental curricular reform in chemistry (Canelas, 2015; Canelas *et al.*, 2017; Hall *et al.*, 2014). Curricular reform focused on first-year and sophomore courses, because that is when most decisions to leave science are made by undergraduates (Seymour and Hewitt, 1997). At Duke, the majority of incoming students often have a good grasp of foundational quantitative chemistry concepts. Therefore, the General Chemistry I course up until 2009 focused on more advanced topics. Unfortunately, this presented a major prior-experience obstacle for some students from traditionally marginalized, UR groups. Due to disparities in K–12 education, African-American or LatinX students with the top 1% of math Scholastic Aptitude Test (SAT) scores for their demographic were often still in the lowest quartile of scores for their entering class at Duke, and before the curricular reform they had an 85% chance of earning a "C", "D," or "F" in this class (Hall *et al.*, 2014). To correct for this institutionalized and inequitable "weeding out" feature, chemistry faculty created a new course, *Introduction to Chemistry and Chemical Problem Solving*, explicitly focused on quantitative problem solving in chemistry that was taught using a flipped-classroom format (Canelas, 2015). Other courses were also adjusted, making them either more foundational or more advanced to provide four curricular tracks tailored to students' previous experiences and exposures (Canelas, 2015). The curricular overhaul has greatly improved performance and retention of students from historically UR groups in chemistry-requiring STEM majors. Examination of baseline data for graduates from 2009 to 2012 (red bars in Figure 1) shows that 32% of all students had STEM majors, but only 18% of students in UR groups had STEM majors; among female UR students with lowest quartile math scores, the rate was even lower at 12% (Figure 1; Hill and Canelas, 2014; Canelas, 2016). However, following the curricular overhaul, participation rates in these majors by UR groups has increased significantly (blue bars in Figure 1). Although participation in STEM majors is still lower for UR groups compared with WR peers, this growth indicates a shift toward parity and a closing of this achievement gap.

The second barrier, low levels of engagement of undergraduates from UR groups with the institution's scientific community, was addressed by the creation of Duke's BioCoRE, funded

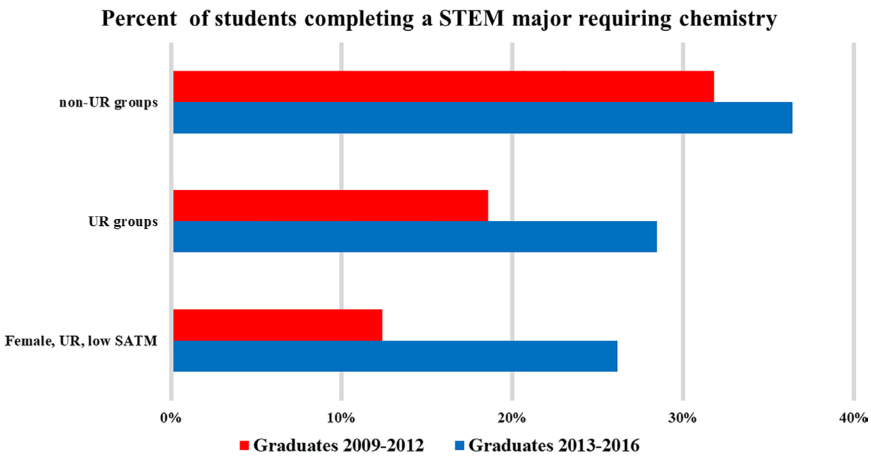

FIGURE 1. Undergraduate STEM major completion rates: a comparison of outcomes before (Graduates 2009–2012, $N = 6560$) and after (Graduates 2013–2016, $N = 6743$) a major curricular revision in the chemistry department. Low SAT mathematics (SATM) is the group of students who are at the bottom quartile for their matriculating class on the SAT mathematics or corresponding ACT mathematics section.

jointly by Duke and the NIH via an Initiative for Maximizing Student Development (IMSD) 5-year grant (Conwell, 2013). BioCoRE purposefully designs programs to address inadequacies for faculty, graduate, and undergraduate students so that synergies between these groups are exploited in a vertically integrated manner. BioCoRE seeks to level the playing field by facilitating the exploration of scientific research opportunities for students belonging to historically UR groups and/or financially disadvantaged families by providing a community of scholarship and intensive support to those who find a research career appealing.

Research Questions for This Study

In this case study, we aim to answer a series of research questions: How do the academic experiences of science students at Duke University impact their career goals throughout training? How do undergraduate goals and experiences in science align when comparing students who identify as belonging to UR groups with those in WR groups in the specific context of our institution? How does intervention by the Duke BioCoRE program impact students' interests, experiences, and intentions with regard to lifetime in careers scientific research? At Duke, our students attend a predominantly white institution and are in a predominantly pre-medical environment. We describe and discuss 1) BioCoRE's approach (undergraduate components) for achieving inclusion excellence at Duke; 2) a new survey instrument and insights gained from participant responses; and, 3) details about how the BioCoRE program seeks to address findings from surveys in terms of student retention in scientific research career tracks.

METHODS

The BioCoRE Program: Undergraduate Component

Ethics Statement. Duke University's Internal Review Board was appropriately consulted about our reporting of results from the evaluation of our institutional program. The work reported herein was conducted following the guidelines set forth by Duke University's Institutional Review Board through approved IRB protocol number 2019-0354: "Academic Experiences and Career Goals of Students in Science."

Overview and Rationale. Published evaluations of the highly successful Meyerhoff program indicated that the five components most valuable to their students are the financial support, community, study groups, and summer bridge and research programs (Maton *et al.*, 2012). Building upon these known best practices, the BioCoRE program for undergraduates has components in research, financial support, community building, and professional development that are summarized in Figure 2. All of BioCoRE's programmatic efforts aim at fostering cultural capital, which has been shown to be important in developing talent in science pathways (Gazley *et al.*, 2014; Thompson and Jensen-Ryan, 2018). Examples of these efforts included:

- Laboratory meetings: Scholars presented their research to fellow undergraduate BioCoRE Scholars to gain confidence in their lab work, practice scientific communication, and develop bonds and support structures through their cohort of scholars. This sharing was critical to create an affirming community of inclusion and kindness, which is important for broadening participation in STEM career pathways (Estrada *et al.*, 2018).
- Science Squads were designed to serve as intentionally created, vertically integrated mentorship teams, with faculty, undergraduates, and graduate students forming close connections and mentoring relationships across scientific disciplines. Science Squads met in informal settings and facilitated scientific development beyond typical interactions between students and professors, allowing an ongoing "career coaching" relationship to be established (Williams *et al.*, 2016).
- Monthly professional development workshops cycled between various topics such as increasing self-efficacy, managing implicit bias, setting scientific goals, developing as a leader, exploring professional pathways, and giving effective scientific presentations.
- The *What Makes Me a Scientist* series centered on scientists storytelling about their paths to science, and this program exposed undergraduate and graduate students to many different types of scientific careers early in their training. The early exposure sought to reduce attrition from the scientific workforce by increasing awareness about many different career opportunities and the nonlinearity of the careers of many successful scientists. Following each seminar, students engaged in small-group discussions to identify similarities between themselves and the presenting scientists.
- *Dinner and Dessert* connected students with faculty in an informal setting to deepen mentor–mentee relationships, demystify the PhD training experience, and provide another avenue to learn about the reality of research careers. Faculty spoke about their paths to careers in research, including

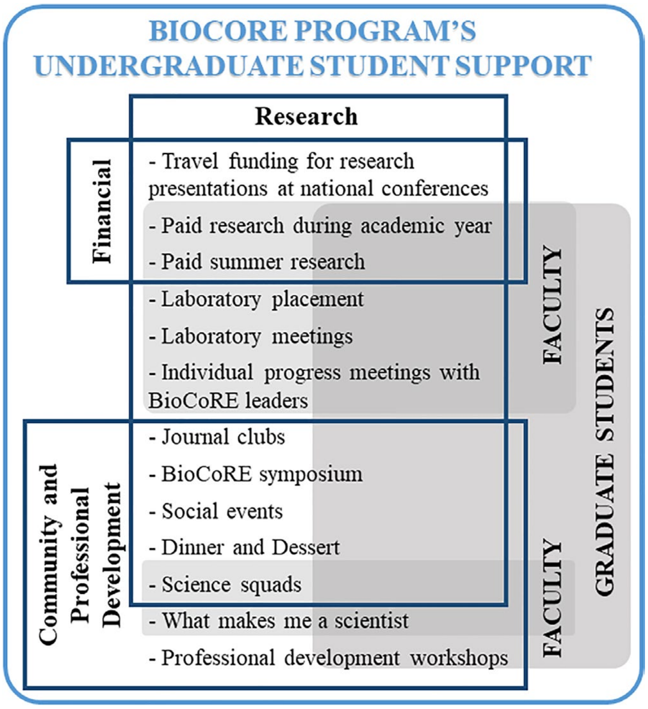

FIGURE 2. Illustrative examples of research, financial, and community support for undergraduate BioCoRE Scholars, including intentional interactions with graduate students and faculty.

successes, failures, obstacles, and changes of direction. Faculty also provided important insights into how they made decisions as they navigated key career transition points.

These events were held jointly with undergraduates and science PhD students and created many opportunities for informal, vertically integrated mentoring. We hypothesize that authentic development of cultural capital in science over time occurred for BioCoRE undergraduate scholars. Finally, programming also aimed to increase the bonds between undergraduates in the cohort and included regular social events, such as cookouts and group outings (e.g., seeing the movie *Hidden Figures*).

Application Process and Scholar Selection. Interested undergraduates applied to become BioCoRE Scholars during the Spring semesters of their first year of college. The timing allowed faculty and staff a small window in the Fall semester to get to know applicants before recommendation requests and BioCoRE Scholar selection. Applications were first evaluated by a committee for program fit based upon a short student-authored essay, stated interests on the application, any known information from internal department assessments or surveys during the Fall term, as well as recommendation letter information. Interviews of finalists by the BioCoRE director were the last step in the Scholar selection process. The goal of these interviews was to confirm understanding of program expectations with all candidates and identify candidates showing the highest levels of enthusiasm and curiosity about laboratory work and aptitude for lifetime research careers in science as opposed to careers in patient-centered medicine. Scholars were appointed as rising sophomores and through their senior years.

Scholar Eligibility and Appointment Overview. From 2013 to 2017, five cohorts of Scholars were selected. Each class of 10–13 students was composed of undergraduates who either met the NIH eligibility criteria (IMSD-funded Scholars) or who were internally funded based upon additional internal diversity criteria, such as sexual or gender identity or other self-identified traits that led to their contribution to a diverse group (two slots per year). The NIH eligibility criteria included individuals from historically UR racial and ethnic groups in addition to individuals with disabilities and/or disadvantaged economic backgrounds (NIH, 2017). Cohort sizes, by year, were: 10 in 2013, 12 in both 2014 and 2015, and 13 in both 2016 and 2017. Figure 3 illustrates the timeline of the institutional implementations of inclusion programs discussed in this case at a research-intensive, private university in the southern United States.

Research and Development Opportunities

Affiliations with Laboratories. BioCoRE leaders assisted Scholars with placement in the Fall of their sophomore years by introducing them to laboratory groups that both matched the students' stated research interest areas and were led by BioCoRE Faculty Affiliates with a good track record for mentoring students and supporting diversity. In a small number of cases, the students had already affiliated with a laboratory through their own initiative. These Scholars did not change laboratories unless they requested a change. Instead, we invited their research advisors to become BioCoRE Faculty Affiliates, which meant they committed to the values and mission of the program, received invitations to our events, and engaged in BioCoRE initiatives such as faculty development activities. The vast majority of students stayed in the same laboratory throughout their multiyear appointments.

Research Time Periods and Structures. BioCoRE Scholars were appointed to the program for three academic years (six semesters and two summers). IMSD funding paid for research efforts by undergraduates in the BioCoRE program for up to four semesters and one summer through an hourly wage for tracked time spent on research activities. In addition to this paid research, students were encouraged to spend their unfunded semesters continuing their research projects for independent study course credit, which is a requirement for most of our science majors. All Scholars had the option to participate in one summer of program-funded research effort. Some students spent the other summer continuing their research on our campus with other funding, such as through fellowships offered by departments or the Undergraduate Research Support Office or working on grant-funded research supported by their research advisors. Other students participated in research programs at other locations, took courses, or engaged in other cocurricular activities, such as our popular global education and study abroad programs. Because Duke University is a liberal arts institution, we felt it was important that students have the flexibility to explore various options for at least part of the time they were Scholars. The expectation during the Fall and Spring semesters was that Scholars spent at least 10 hours per week engaged in

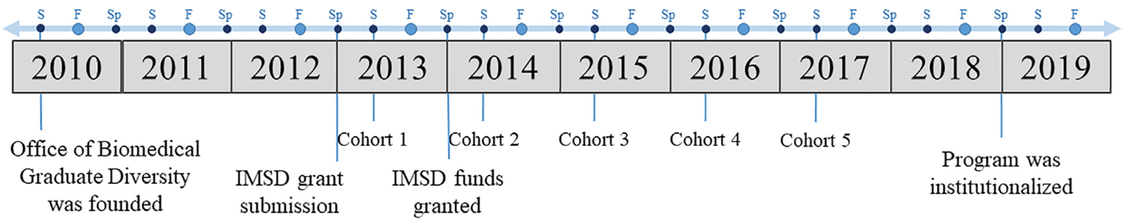

FIGURE 3. **Fall (F), Spring (Sp) and Summer (S) semester timeline for the BioCoRE program. The graduate student portions of the program have been fully institutionalized; the undergraduate program is partially institutionalized as we seek extramural funding after a small gap.**

paid work on their mentored research activities in the sciences. Funding also covered travel and attendance at a national scientific meeting in the scholars' senior years.

During summers, Scholars had the opportunity to join summer research. This opportunity included: 1) 40 paid research hours per week for 8 weeks, 2) a research-intensive laboratory experience in which undergraduate students worked with and met regularly with a BioCoRE graduate student who served as an individual coach, 3) housing to mitigate the need for students to find other employment, and 4) several programmatic events. Events included workshops designed to sustain momentum toward science careers and prepare competitive applications for research-intensive graduate programs in the biosciences, weekly meetings with their peers and a mentor, mock interviews with faculty, and opportunities to give formal presentations of their research findings in both peer environments and public forums. Research presentations by undergraduates took place at the BioCoRE symposium during the summer and national conferences such as the Annual Biomedical Research Conference for Minority Students or the Society for Advancement of Chicanos/Hispanics and Native Americans in Science.

The BioCoRE Symposium. At the end of the summer program, all BioCoRE summer undergraduate researcher participants presented posters featuring their summer research findings at the annual BioCoRE symposium. The symposium was an annual 2-day event that fostered communication between faculty/administrators and students from Duke and partner institutions. The goals of the symposium were to: 1) build bridges with partner institutions; 2) increase the number of undergraduate students from feeder institutions who pursue the PhD; 3) improve education, research, and mentoring; 4) facilitate smooth transitions of undergraduate students to graduate education; 5) facilitate smooth transitions of graduate students and postdoctoral associates (postdocs) into the biomedical workforce; and 6) increase the sense of community engagement between our BioCoRE Scholars and scholars in similar programs at institutions in the region. The event was unique, in that it combined cutting-edge science talks with discussions and workshops on pedagogy and effective practices in science student training and mentoring. The first day was devoted to professional development, and it split participants into two tracks: workshops specifically designed for faculty and administrators and a separate series of workshops for students and postdocs relevant to their training experiences. The second day celebrated science and community, with poster presentations by undergraduate and graduate students and oral presentations by faculty from diverse backgrounds, postdocs, and graduate students from different institutions.

By the time BioCoRE Scholars graduated, they had a firm grasp of the nature of STEM PhD work through their exposure to research labs, professional development programs, both local and national conferences, and extensive interactions with graduate students, postdocs, and faculty. Lists of professional development workshops and keynote speakers at the BioCoRE symposium by year are provided as Supplemental Material.

Program Assessment

Survey Development. To assess students' gains from community of scholarship and science persistence programs, researchers commonly use self-reported survey evaluations of participants in the program with a group of non-participants for comparison (Ashley *et al.*, 2017). The Meyerhoff program used the group of students who were accepted in the program but declined the offer and instead elected to pursue a STEM major elsewhere or who enrolled in four or more STEM courses in their freshman year elsewhere as a comparison group to evaluate their goals (Maton *et al.*, 2012). In the case presented herein, academic and research experiences as well as career goals were assessed through a survey instrument developed by the BioCoRE leaders in concert with chemistry faculty. This survey aimed to assess students' true interests in research careers and/or clinical medical professions using sets of parallel Likert-scale statements that were phrased in various ways throughout the survey. Students rated 24 of these statements based on Likert-scaled estimations (1 = strongly disagree, 2 = somewhat disagree, 3 = neither agree or disagree, 4 = somewhat agree, and 5 = strongly agree). Statements were grouped into the following categories in the survey:

Academic Plans: "I plan to major in chemistry"; "I plan to minor in chemistry"; "I plan to attend a health-related professional school"; "I plan to attend graduate school in the natural sciences"; "I plan to attend graduate school in the biomedical sciences"; "I am planning a pre-med course of study at Duke."

Scientific Experiences: "I already know what it is like to conduct scientific research in a laboratory"; "I am interested in learning more about behavioral science research"; "I am interested in learning more about biomedical research"; "Outside of the class, I have worked in a science laboratory conducting research"; "I will conduct laboratory research while attending Duke"; "In the future, I would like to spend at least part of one summer conducting scientific research in a laboratory."

Career Pathways: "I am interested in pursuing a career in engineering"; "I am interested in a career in law or public policy"; "I am interested in pursuing a career in quantitative sciences"; "I do not want a career in healthcare that involves working directly with patients"; "I am interested in applying to MD/PhD programs to combine my interests in medicine research"; "I am interested in a career focused on scientific research"; "My future plans have changed during my time at Duke University."

Academic Self-Confidence: "Preceding classes prepared me adequately for the current chemistry class"; "I feel comfortable asking for help if I need it"; "I expect to do well in my chemistry classes"; "I expect to do well in my science classes"; "I expect to do well in my nonscience classes."

The questionnaire also included opportunities for optional free-form responses in each section. In addition, students were prompted with two statements and asked to respond on a scale from 0 to 100 for each item. For these items, slider bars were used to measure students' levels of interest in pursuing two different avenues: "a lifetime career in scientific research" and "a career with direct patient contact (physician, nurse, PA, dentist, pharmacist, etc.)." After these items, participants also rated "level of certainty related to career plans," where 100 represented a high level of interest or certainty. Each of the sliding bars were initially placed at 50, and students could not continue to the next section of the survey unless they had clicked on and moved all of the bars (some chose to move them back to 50, but requiring movement of the bars assured that participants did not just skip this step). For simplicity and consistency, responses with a range from 0 to 100 were rescaled to a 1 to 5 range in our analysis.

Validation of Survey Data. To validate students' responses, we ran an exploratory factor analysis to verify the internal relationships among similar items in the survey. An exploratory factor analysis demonstrates the internal validity of these constructs as composites of statistically-aligned questionnaire items. We sought a simple structure that represented a clear pattern of distinct factor loadings. The scree plot presented in Figure 4 was obtained using all the surveys available to this study ($n = 3099$) and suggests a curve after components 4 and 5. The plot suggests that the first four or five factors be retained for factor rotation. In this study, we use principal axis factoring to extract the least number of factors while seeking common variances, followed by oblique rotations to permit the correlation among factors. Reviewing the alignment of variables and factor loadings, the researchers pursued a four-factor model and derived the following factors of interest to students: medical profession, graduate school, academic self-confidence, and laboratory scientific research. The factor analysis reduced our analysis to 19 survey items. The final rotated component matrix is reported in Table 1. Note that the institution does not allow students to formally declare their majors and minors during the first year of study, and a minor in chemistry is embedded in the curriculum for most of the pre-med degrees at the studied institution, which is why the statement for a chemistry minor is related to a student's interest in the medical profession. Also, note that, within the Likert-scale survey items related to a positive interest in the medical profession, items "I am interested in pursuing a career in engineering" and "I do not want a career in health care that involves working directly with patients" may reflect disinterest in a medical profession. The values and statements for these items were inverted to align with the ordinal scale of the remaining survey items. Inversing these responses resulted in a positive and high internal scale reliability. Scale reliability is evaluated using Cronbach's alpha (Cronbach, 1951), where the α value represents the percentage of the observed variance that is due to variance in the true score rather than error. The interfactor correlations are low, as one would expect from a well-designed survey instrument. Most of the correlations are statistically significant at $p < 0.0001$, but the practical significance of these associations is small. Although the eventual factor structure includes four factors, the factor "Academic self-confidence" was removed from the analysis, because it is outside the scope of the paper.

Survey Deployment. The survey was deployed to two groups: undergraduates taking chemistry courses and BioCoRE students.

Chemistry Courses. Surveys were deployed to the general undergraduate student population during the Fall and Spring semesters of two full academic years through five different chemistry courses: *Introduction to Chemistry, Core Concepts in Chemistry, Organic Chemistry 1, Organic Chemistry 2, and Modern Applications of Chemical Principles* (please see Supplemental Material for full survey). The overall chemistry curriculum and additional descriptions of some of these courses have been previously reported (Hall *et al.*, 2014; Canelas, 2015; Canelas *et al.*, 2017, 2019; Cooke and Canelas, 2019; Barger *et al.*, 2018). These chemistry courses were chosen because they are medium- to large-sized classes widely taken by science students whether or not they major in chemistry. Surveying in chemistry classes captures the authentic responses of undergraduates at the earliest point in their science course work. The courses span a range of student experience: >90% of the students enrolled in *Introduction to Chemistry* are first-year undergraduates, while

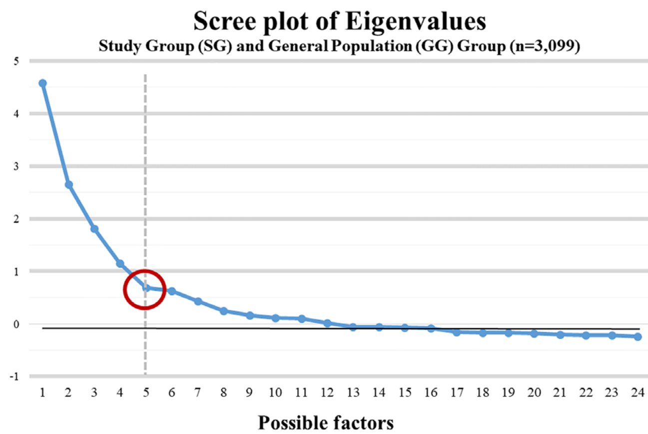

FIGURE 4. Scree plot showing distribution of factors by their eigenvalues. An eigenvalue is the variance of the factor. Because this is an unrotated solution, the first factor will account for the most variance, the second will account for the second-highest amount of variance, and so on. The plot displays an "elbow" (shown by the red circle). This point of the curve represents the threshold chosen for retention of the initial factors extracted from the observed variables that maximize the variance accounted for.

TABLE 1. Factor loadings and communality estimates based on a a principal axis factoring with promax rotation for 24 items from the BioCoRE survey[a]

Factor of interest[b]	Likert-scaled survey items[c]	Factor loadings	Communality estimate (h-sq)
Medical profession ($\alpha = 0.89$)[a]	I plan to attend a health-related professional school.	0.94	0.88
	I am planning a pre-med course of study at Duke.	0.92	0.86
	I am not interested in pursuing a career in engineering.[d]	0.48	0.27
	I want a career in healthcare that involves working directly with patients.[d]	0.76	0.58
	A career with direct patient contact	0.85	0.72
	I plan to minor in chemistry.	0.58	0.36
Graduate school ($\alpha = 0.77$)[a]	I plan to attend graduate school in the natural sciences.	0.62	0.42
	I plan to attend graduate school in the biomedical sciences.	0.70	0.51
	I am interested in learning more about biomedical research.	0.48	0.37
	In the future, I would like to spend at least part of one summer conducting scientific research in a laboratory.	0.55	0.39
	I am interested in applying to MD/PhD programs to combine my interests in medicine research.	0.59	0.45
	I am interested in a career focused on scientific research.	0.75	0.61
Academic self-confidence ($\alpha = 0.75$)[a]	Preceding classes prepared me adequately for the current chemistry class.	0.52	0.28
	I feel comfortable asking for help if I need it.	0.51	0.26
	I expect to do well in my science classes.	0.75	0.57
	I expect to do well in my chemistry classes.	0.82	0.68
Laboratory scientific research ($\alpha = 0.74$)[a]	I already know what it is like to conduct scientific research in a laboratory.	0.76	0.58
	Outside of the class, I have worked in a science laboratory conducting research.	0.78	0.60
	I will conduct lab research while attending Duke.	0.53	0.42

[a]Ten items failed to load onto one of the four observed factors.
[b]α = Cronbach's alpha.
[c]1 = strongly disagree, 2 = somewhat disagree, 3 = neither agree or disagree, 4 = somewhat agree, and 5 = strongly agree, unless otherwise specified.
[d]Survey values and statements were inverted to align sentiment with factor of interest.

Modern Applications of Chemical Principles was comprised of almost entirely upperclass students (an illustrative section of this course had <1% first-year undergraduates, 18% sophomores, 53% juniors, and 29% seniors). The surveys were deployed at the midpoint of the semester, and a very small number of bonus points toward the course grade were used to incentivize completion of the survey. Deployment from official course websites plus incentivization led to a high survey return rate (89%). Data were subsetted and classified as belonging to the pool for selection of the comparison group if the student taking the survey was not a BioCoRE Scholar or if the survey was taken before the student became a BioCoRE Scholar.

BioCoRE Surveys. An analogous survey was deployed to BioCoRE undergraduate scholars, who may have also taken the survey as part of their chemistry courses. For the Scholars, the survey was deployed online to participants in the BioCoRE program as a normal part of the program assessment in the 2017 Fall semester, 2018 Fall semester, and 2018 Summer sessions (BioCoRE alumni were not included); these data were classified as the study group. The response rate was 77% for BioCoRE Scholars surveyed outside their classwork.

Additional course- or program-specific feedback was collected from both groups through these surveys, but these items are not part of the analysis presented here. To limit the scope of this study, only survey items that were the same for both groups are discussed. Complete surveys are provided as Supplemental Material. Personal identifying information was included at the end of each survey so that students would receive the credit in their courses (if applicable) and researchers could determine whether or not a student had previously self-identified as belonging to a WR or UR race or ethnic group by matching each survey to additional institutional data. To protect individuals from inadvertent disclosure of their responses, survey responses were de-identified after demographic information was matched.

Data Cleaning. Excel and SAS software were used for managing the survey data and the statistical analyses. For this analysis, the final tally after data cleaning was 3099 surveys taken by 2069 unique students enrolled in chemistry classes and/or participating as BioCoRE Scholars. This is the final number after the following cleaning steps. In the initial raw data set, there were a small number of cases ($n = 57$) in which students started the survey more than one time per semester because they submitted an incomplete set of responses at first attempt. Fifty-two students completed the entire survey twice in the same semester because they were enrolled in two different courses that offered bonus points for the same survey. In both of these cases, only the first complete survey taken by the student was kept in the database, assuming that a student was more careful in choosing responses in the first complete attempt. Finally, 22 surveys completed by individuals who did not input sufficient personal identifying information for matching to records were removed from the database. There were 3055 surveys completed by students who were not BioCoRE Scholars at the time of survey completion; 44 surveys taken by students *after* they became BioCoRE Scholars; and 13 BioCoRE Scholars who took the survey twice. The set of 3055 surveys was analyzed and referred to as the general population group (GG). A subset of the general population group was chosen as the comparison group, a total of 500 surveys. The 31 surveys taken by BioCoRE Scholars are referred to as the study group.

A comparison group was derived from the 3055 surveys taken by non-BioCoRE students and deployed in the chemistry courses. The authors randomly sampled 500 students from the 3055 non-BioCoRE respondents, matching group composition primarily based on Admission Office's rubric scores for strength of high school curriculum and high school achievements. These "reader ratings" for curriculum score and achievement score, respectively, are on a five-point scale where 5 is the highest score possible; the mean value for each group is reported, and the error shown is the standard error of the mean (Table 2). UR status and prematriculation interest in biology and chemistry were also considered in creation of the comparison group. These attributes seem most predictive of eventual academic outcomes and directions. Because a true control group is not possible for practical reasons, the comparison groups allows the authors to evaluate the impact of the BioCoRE program by comparing similar populations of students. Table 2 summarizes the demographics of the groups analyzed in this article. Surveys were classified as from participants belonging to WR or UR populations per NIH definitions (NIH, 2018).

RESULTS

For simplicity, we described the survey responses as "agreeing" when students somewhat agreed or strongly agreed in their response to a statement. The chi-square test was performed to determine whether there was enough evidence to conclude that the WR and UR groups (categorical independent variable) were different within the comparison group with respect to their survey responses (categorical dependent variable). There is work demonstrating the importance of the intersectionality of identities when examining individuals' research and science experiences (Morton and Parsons, 2018; Ong *et al.*, 2018; Byars-Winston and Rogers, 2019). However, due to the limited sample size, we only considered program participation and race/ethnicity. We did not attempt to divide the groups up in any additional ways (such as by gender) in our final analysis. Tables 3, 4, 5, and 6 indicate the factors of interest for this study: plans for a medical profession, for graduate school, and laboratory scientific research experience.

We asked the following questions for the global population and the comparison group (n = 500) in the absence of the BioCoRE intervention: How do the academic experiences of science students at Duke impact their career intentions at different times throughout training? How do these experiences and career intentions differ for students who identify as belonging to groups historically UR in science compared with those in historically WR groups?

General Population Group.

In this section, we analyze Table 3 and Figure 5, which correspond to the surveys by the general population group. Duke

TABLE 2. Description of sample and groups: academic preparation (reader ratings), academic interests, and demographics

Description of sample	Comparison group	Study group
Number of students (% in group)		
Total number of responses	500	31
Mean reader rating in high school		
Achievement score[a]	4.36 ± 0.03	4.37 ± 0.13
Curriculum score[a]	4.10 ± 0.03	4.12 ± 0.12
Academic interests		
Prematriculation interest in biology (ranked 1 or 2)	157 (31%)	14 (45%)
Prematriculation interest in chemistry (ranked 1 or 2)	79 (16%)	7 (23%)
Self-reported demographic information		
Gender identity		
Female	343 (69%)	19 (61%)
Male	157 (31%)	12 (39%)
Total well represented (WR)-identifying students	288 (58%)	12 (39%)
White	176 (35%)	8 (26%)
Asian	100 (20%)	4 (13%)
Non-Hispanic or did not indicate an ethnicity	12 (2%)	0 (0%)
Total underrepresented (UR)-identifying students	212 (42%)	19 (61%)
Black	104 (21%)	12 (39%)
Hispanic/Latino	95 (19%)	7 (23%)
Native Hawaiian/Pacific Islander	2 (0%)	0 (0%)
American Indian or Alaskan Native	11 (2%)	0 (0%)

[a]Reader ratings are assigned to each application upon review by the Office of Undergraduate Admissions. Each application is read by two reviewers, each of whom assigns a score of 1–5 on six different scales. Scales include strength of high school curriculum, high school achievements, application essay, extra- and cocurricular experiences, letters of recommendation, and test scores. These ratings may be used as proxies for academic background and preparedness.

TABLE 3. Chi-square tests showing a comparison between surveys submitted by students of any gender in the general population group who belonged to either historically well-represented (WR) or underrepresented (UR) racial/ethnic groups in science[a]

Factor of interest	Item	Survey items	Percent of students who agreed or strongly agreed: Total (n = 3055)	WR (n = 2204)	UR (n = 851)	Chi-square test (p values)[b]	Average and SEM: WR (n = 2204)	UR (n = 851)
Medical profession	1	I plan to attend a health-related professional school.	70%	69%	72%	0.001	3.84 ± 0.03	3.96 ± 0.03
	2	I am planning a pre-med course of study at Duke.	68%	67%	70%	0.450	3.75 ± 0.03	3.82 ± 0.03
	3	I am not interested in pursuing a career in engineering.[c]	71%	68%	77%	<0.001	3.78 ± 0.03	4.14 ± 0.03
	4	I want a career in healthcare that involves working directly with patients.[c]	73%	74%	73%	<0.001	4.04 ± 0.03	4.09 ± 0.03
	5	A career with direct patient contact	74%	73%	76%	0.004	3.98 ± 0.05	4.07 ± 0.03
	6	I plan to minor in chemistry.	45%	44%	48%	0.002	2.98 ± 0.03	3.08 ± 0.03
Graduate school	7	I plan to attend graduate school in the natural sciences.	28%	28%	28%	0.395	2.65 ± 0.02	2.67 ± 0.02
	8	I plan to attend graduate school in the biomedical sciences.	28%	29%	24%	0.012	2.63 ± 0.02	2.46 ± 0.02
	9	I am interested in learning more about biomedical research.	76%	78%	71%	<0.001	4.07 ± 0.02	3.87 ± 0.02
	10	In the future, I would like to spend at least part of one summer conducting scientific research in a laboratory.	79%	80%	76%	0.007	4.23 ± 0.02	4.1 ± 0.02
	11	I am interested in applying to MD/PhD programs to combine my interests in medicine research.	46%	47%	43%	0.003	3.14 ± 0.03	3.06 ± 0.03
	12	I am interested in a career focused on scientific research.	41%	42%	37%	<0.001	3.06 ± 0.02	2.87 ± 0.02
Laboratory scientific research	13	I already know what it is like to conduct scientific research in a laboratory.	59%	64%	47%	<0.001	3.59 ± 0.03	3.10 ± 0.02
	14	Outside of the class, I have worked in a science laboratory conducting research.	48%	54%	34%	<0.001	3.25 ± 0.03	2.54 ± 0.03
	15	I will conduct laboratory research while attending Duke.	84%	86%	79%	<0.001	4.39 ± 0.02	4.19 ± 0.02

[a]Percentages indicate the proportion of students who agreed or strongly agreed. Averages are based on response ranges of 1–5 (where 1 = strongly disagree and 5 = strongly agree) for each item in the internal surveys administered to the control group.
[b]Chi-square test p values are for differences between WR and UR subgroups within the general population group.
[c]Survey values and statements were inverted to align sentiment of the factor of interest.

University has a strong pre-med undergraduate bias. As with previous work (Canelas *et al.*, 2017), our data show that many more Duke students aim to pursue health-related professional degrees (items 1–5: 68–74%) rather than graduate degrees in the natural or biomedical sciences (items 7 and 8: 28%). Evidenced by chi-square p values in the graduate school and medical profession factors of interest, UR students showed a slightly greater skew away from graduate degrees in sciences and toward health-related professional degrees. McGee and Keller (2007) indicated that undergraduate students who aspire to enter medical schools, irrespective of their ethnicity or gender, uniformly display a strong desire to help others more directly and immediately. Item 5 in our data aligns with McGee and Keller's findings, with high percentages of agreement for a career with direct patient contact, but the data show a difference between WR and UR groups (item 5: chi-square $p < 0.001$). Of students who took the survey, 71% want a career in healthcare that involves working directly with patients. Thus, Duke University has a strong pre-med undergraduate bias.

In their responses about initial interests in natural sciences, UR and WR groups scored similarly in the survey (item 7). Thus, at early stages of science training at this institution, there is no racial or ethnic differentiation among students who show interest in their intent to pursue scientific research (Figure 5a). This supports similar findings in a range of other institutional settings (Garrison, 2013; Meyers *et al.*, 2018). To summarize this point, Garrison notes that "Among college freshmen, race-ethnic differences in plans for a science or engineering major are very small and have little impact on the ultimate level of underrepresentation" (Garrison, 2013, p. 362). In most other

TABLE 4. Chi-square tests showing a comparison between surveys submitted by students of any gender in the comparison group (CG) who belonged to either historically well-represented (WR) or underrepresented (UR) racial/ethnic groups in science

Factor of interest	Item	Survey items	Percent of students who agreed or strongly agreed[a]			Chi-square test (p values)[b]	Average and SEM	
			Total (n = 500)	WR (n = 288)	UR (n = 212)		WR (n = 288)	UR (n = 212)
Medical Profession	1	I plan to attend a health-related professional school.	63%	66%	58%	0.0779	3.71 ± 0.09	3.39 ± 0.12
	2	I am planning a pre-med course of study at Duke.	62%	64%	58%	0.2315	3.64 ± 0.10	3.33 ± 0.12
	3	I am not interested in pursuing a career in engineering.[c]	64%	62%	67%	0.2105	3.55 ± 0.10	3.75 ± 0.11
	4	I want a career in healthcare that involves working directly with patients.[c]	67%	71%	62%	0.029	4.16 ± 0.08	3.85 ± 0.11
	5	A career with direct patient contact	67%	72%	59%	0.0029	3.53 ± 0.09	3.12 ± 0.13
	6	I plan to minor in chemistry.	35%	37%	33%	0.3101	2.84 ± 0.09	2.51 ± 0.11
Graduate School	7	I plan to attend graduate school in the natural sciences.	26%	27%	25%	0.5051	2.67 ± 0.08	2.52 ± 0.09
	8	I plan to attend graduate school in the biomedical sciences.	26%	32%	18%	0.0003	2.69 ± 0.08	2.15 ± 0.08
	9	I am interested in learning more about biomedical research.	67%	74%	57%	<0.0001	3.9 ± 0.07	3.48 ± 0.09
	10	In the future, I would like to spend at least part of one summer conducting scientific research in a laboratory.	76%	82%	75%	0.0002	4.26 ± 0.06	3.90 ± 0.08
	11	I am interested in applying to MD/PhD programs to combine my interests in medicine research.	43%	49%	36%	0.004	3.16 ± 0.08	2.83 ± 0.10
	12	I am interested in a career focused on scientific research.	41%	46%	35%	0.0174	3.16 ± 0.08	2.76 ± 0.09
Laboratory Scientific Research	13	I already know what it is like to conduct scientific research in a laboratory.	47%	55%	37%	<0.0001	3.30 ± 0.08	2.81 ± 0.09
	14	Outside of the class, I have worked in a science laboratory conducting research.	38%	48%	25%	<0.0001	2.99 ± 0.10	2.21 ± 0.10
	15	I will conduct laboratory research while attending Duke.	78%	83%	71%	0.0012	4.29 ± 0.06	4.02 ± 0.07

[a]Percent of students who agreed or strongly agreed and average responses between 1 and 5 (where 1 = strongly disagree and 5 = strongly agree) for each item in the internal surveys administered.
[b]Chi square test p values are for differences between WR and UR subgroups within the comparison group.
[c]Survey values and statements were inversed to align sentiment of the factor of interest.

items, there were statistically significant (though sometimes small) differences between UR and WR responses.

Survey items under the laboratory scientific research factor of interest (items 13–15) constituted the largest and most striking differences between the UR and WR groups. Similar to a 2012 institutional self-study, the survey responses revealed that students from traditionally UR groups are *much less likely* to have precollege exposure to laboratory research than their WR peers, and the gap persists as they participate in research at lower rates than their WR peers over all 4 years of college (Figure 5c and d). We analyzed changes over time across mean cohort data. Figure 5c and d shows a clear difference in laboratory experience and confidence with scientific research outside class throughout undergraduate training when comparing students from UR and WR demographic groups in the general population. Only 47% of UR students agreed with the statement "I already know what it is like to conduct scientific research in a laboratory," as compared with 64% of WR students (a gap of 17% in item 13). And only 34% of UR students reported conducting research outside class, as compared with 54% of WR students (a gap of 20% in item 14). Additionally, the gap in item 15, with regard to their future plans to conduct laboratory research, was also statistically significant with a 7% difference. These differences suggest an existing institutional challenge: WR students are much more likely to have a laboratory research experience than UR students despite similar initial levels of interest in research. Because laboratory research experiences are critical to success in research career pathways (Kuh, 2008; Murray *et al.*, 2016), the existence and persistence of this gap must be addressed. Methods for addressing this disparity were tested by the BioCoRE program; the results from this program effort are detailed in the following sections.

TABLE 5. Chi-square tests showing a comparison between surveys submitted by students of any gender in the BioCoRE group and the comparison group (CS).

Factor of interest	Item	Survey items	Percent of students who agreed or strongly agreed[a] Total (n = 531)	Comparison group (n = 500)	Study group (n = 31)	Chi-square test (p values)[b]	Average and SEM Comparison group (n = 500)	Study group (n = 31)
Medical profession	1	I plan to attend a health-related professional school.	63%	63%	59%	0.6765	3.58 ± 0.07	3.31 ± 0.34
	2	I am planning a pre-med course of study at Duke.	61%	62%	59%	0.798	3.51 ± 0.08	3.31 ± 0.34
	3	I am not interested in pursuing a career in engineering.[c]	64%	64%	66%	0.8936	3.64 ± 0.07	3.75 ± 0.28
	4	I want a career in healthcare that involves working directly with patients.[c]	68%	67%	81%	0.0957	4.02 ± 0.07	4.50 ± 0.20
	5	A career with direct patient contact	67%	67%	75%	0.3305	3.35 ± 0.08	3.66 ± 0.30
	6	I plan to minor in chemistry.	34%	35%	19%	0.0581	2.70 ± 0.07	2.87 ± 0.47
Graduate school	7	I plan to attend graduate school in the natural sciences.	28%	26%	53%	0.0009	2.61 ± 0.06	3.35 ± 0.27
	8	I plan to attend graduate school in the biomedical sciences.	28%	26%	63%	<0.0001	2.46 ± 0.06	3.63 ± 0.26
	9	I am interested in learning more about biomedical research.	67%	67%	78%	0.1874	3.76 ± 0.06	4.28 ± 0.19
	10	In the future, I would like to spend at least part of one summer conducting scientific research in a laboratory.	77%	76%	91%	0.0559	4.11 ± 0.05	4.56 ± 0.13
	11	I am interested in applying to MD/PhD programs to combine my interests in medicine research.	44%	43%	47%	0.6986	3.03 ± 0.07	3.00 ± 0.31
	12	I am interested in a career focused on scientific research.	43%	42%	72%	0.0008	2.99 ± 0.06	3.97 ± 0.21
Laboratory scientific research	13	I already know what it is like to conduct scientific research in a laboratory.	50%	47%	100%	<0.0001	3.08 ± 0.06	4.53 ± 0.09
	14	Outside of the class, I have worked in a science laboratory conducting research.	42%	38%	100%	<0.0001	2.66 ± 0.08	4.88 ± 0.06
	15	I will conduct laboratory research while attending Duke.	84%	78%	100%	0.0027	4.17 ± 0.05	4.91 ± 0.05

[a]Percent of students who agreed or strongly agreed and average responses between 1 and 5 (where 1 = strongly disagree and 5 = strongly agree) for each item in the internal surveys administered.
[b]Chi-square test p values are for differences between the comparison group and the study group.
[c]Survey values and statements were inversed to align sentiment of the factor of interest.

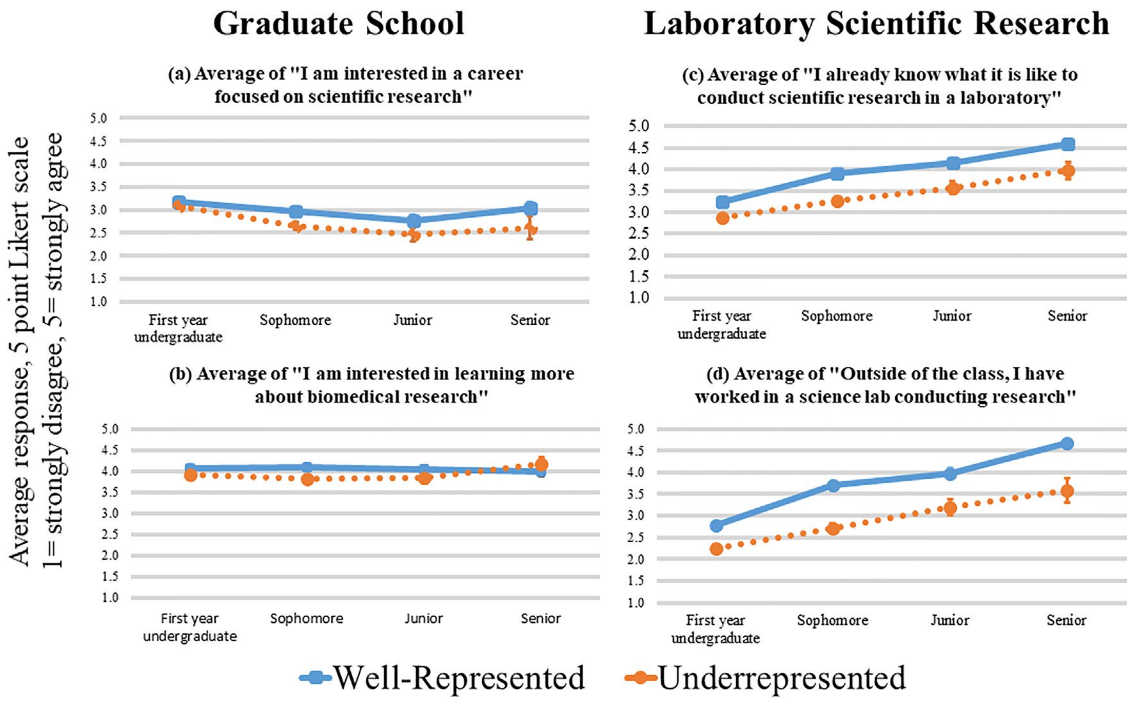

FIGURE 5. Self-reported average level of agreement to survey statements vs. year in college. Well-represented general population group, $n = 2204$. Underrepresented general population group, $n = 851$.

General Population Group and the Comparison Group. In this section, we analyze the differences between Tables 3 and 4, which correspond to the surveys by the general population group (Table 3) and a subset of this group, the comparison group (Table 4). Much as seen in Table 3, items 2 and 7 in Table 4 were not found to be significantly different when comparing WR and UR groups. In addition to these items, items 1, 3, 6, and 15 were not found to be statistically significant in the comparison group. For the most part, the graduate school and laboratory scientific research factors of interest were statistically significant when comparing student responses from historically WR and UR groups in the comparison group (Table 4).

The Study Group. The vision driving the BioCoRE program is rooted in the concept that diversity and inclusion at the institutional level will be improved through a holistic approach involving interventions designed for all stakeholders: undergraduates, graduate students, and faculty. The strategy is to have activities at each stakeholder level that combine to accelerate improvement in the institutional culture and address barriers to a science career for students belonging to UR populations. In this section, we analyze Tables 5 and 6.

Table 5 represents the differences when comparing the study group and the comparison group and indicate that BioCoRE improved laboratory scientific research participation in the study group and familiarity for students. Based on our results, BioCoRE students also had a statistically significant increase in plans for a career focused on scientific research and/or to attend graduate school in the natural and biomedical sciences when compared with the comparison group.

Figure 6 represents responses for select survey items from students from the comparison and the study groups throughout their academic training. It is possible that the BioCoRE program mainly worked well at identifying the students who would generally have more interest in scientific research and/or graduate school. Based on Figure 6, students in the study group were more interested in graduate school and in laboratory scientific research in every stage of their training when compared with the comparison group.

DISCUSSION

Key Findings The culmination of interventions used within the BioCoRE program were imperative in limiting the gap between WR and UR students surveyed about career plans and interest in research-based opportunities. Tangible takeaways from our project are comprehensive; however, our group has extracted key findings useful for institutions and partners to increase the number of UR students matriculating into graduate school:

Early assessment of interest in research-based careers: One gem from our study was the unexpected transparency of students' responses documented from our chemistry course survey. Deployment of a survey in a nonthreatening environment and detached from any sort of program application allowed for objective perspectives from students and led to a strong understanding of the current landscape of the university. This provided an unobstructed view of the mindset of WR and UR students. From an administrative perspective, this creates a baseline at the institution to observe gaps in concepts between groups. Survey tools can include questions related to career goals and understanding of research concepts and may even venture into questions regarding self-efficacy or motivation. This economic-friendly intervention can be

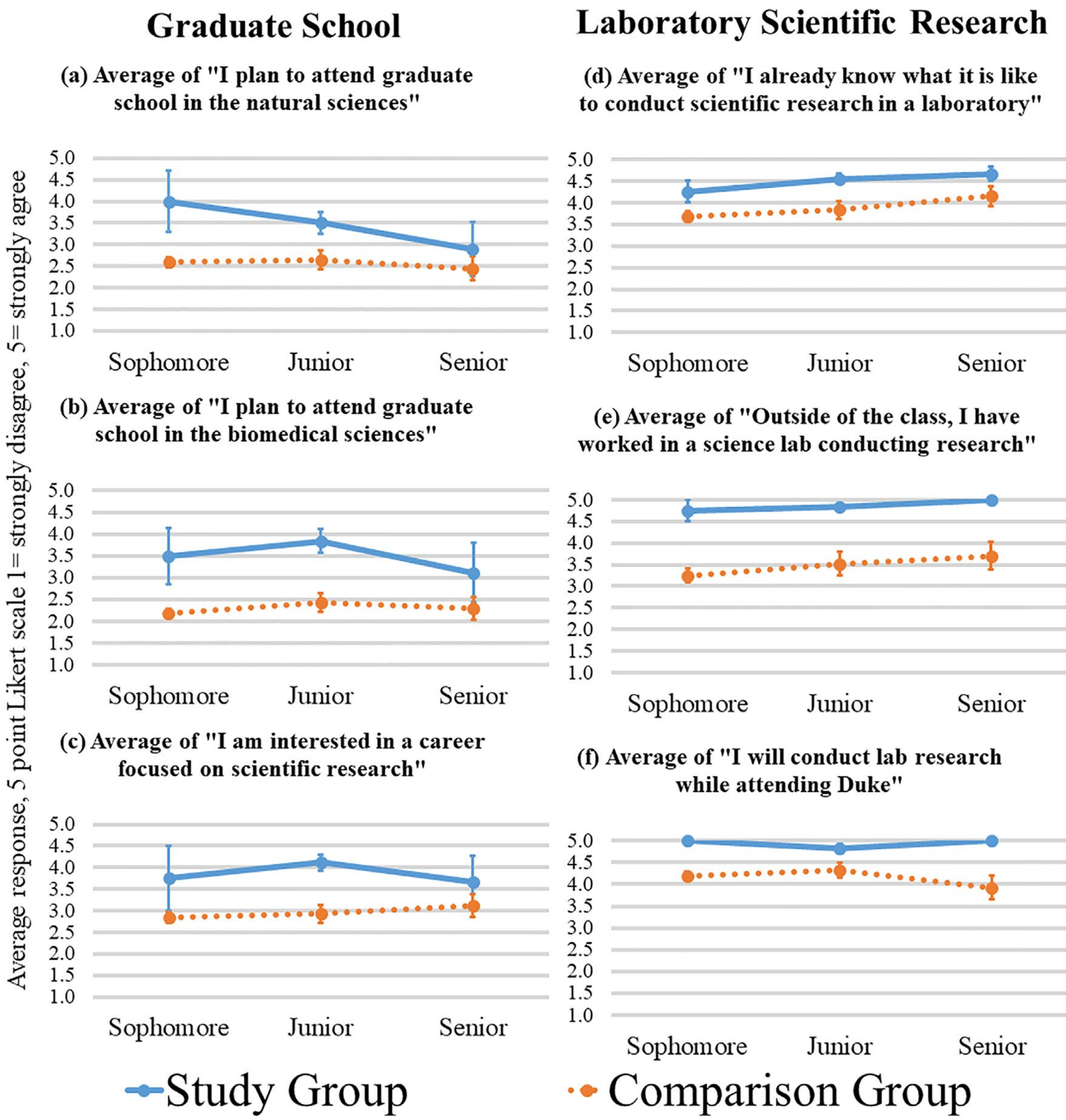

FIGURE 6. Self-reported average level of agreement to survey statements vs. year in college. Study group, $n = 31$. Comparison group, $n = 500$.

used at any level to develop a reference point of student thought.

Professional development for faculty and students: A unique aspect of the BioCoRE program was our ability to provide dual professional development to faculty and UR students through programs such as our BioCoRE symposium. Having an influence on the growth at both ends of the spectrum allowed for training that was bidirectional and offered realistic cause-and-effect scenarios. Ensuring students were aware of the proficiencies and specifics associated with a research career paired well with faculty learning about cultural competencies to create supportive laboratory environments. Furthermore, mentorship from faculty was imperative in students' experiences, yet training for mentorship is not always standardized. Organizations can easily implement programs on either side of this seesaw to reap the benefits across the institution.

Infusion of early research experiences: A wildly popular and effective initiative for broadening UR participation is the innate incorporation of research into the curriculum, most likely done through course-based undergraduate research experiences (CUREs). While our program used funds to pay for UR student research, an alternative option is to infuse research into the laboratory experiences of all students. Straying away from "cookie-cutter" labs, CUREs allow students to fully grasp research in a palpable and applicable way. Institutions can use laboratory funds from student tuition dollars to develop projects for all students, providing opportunities for UR students to be exposed to research at early levels and also in a protected environment. While early research exposure is, for the most part, beneficial to cultivating PhD aspirations during college, identifying students interested in research at an early age has been challenging, as seen in our own BioCoRE selection progress. Integrating research into the natural curriculum will fertilize the entire student population and those UR students with a research mindset will bloom as a result.

Creation of UR-focused communities for research based careers: A sense of community was noted as one of the most central facets of the BioCoRE program. There are many student-led groups across institutions, but forming a department-sponsored group can show solidarity. Having groups of UR students who have collectively united to learn about and cultivate their interest in research is representative of planting a seed within the institution. This community will foster students' sense of belonging and support, not from a self-united standpoint, but from a lens that shows departmental involvement.

How Well Did Our Application and Candidate Selection Process Work?

Some published evidence suggests that feeling fully invested in their laboratory research experiences plays an important role that must be considered when developing talent (McGee *et al.*, 2012; Gazley *et al.*, 2014; McMurtrie, 2016). We wanted to emphasize talent development, as recommended by McGee and coworkers (2012), while selecting individuals open to exploration of science careers regardless of their prior level of experience working in laboratories. Over the course of the BioCoRE program, we learned that a multiphase process is critical for selecting candidates who have a sincere interest in exploring science career pathways. Pre-med students can be very savvy in writing or saying what they think a selection committee wants to hear based upon the program description, and in the first couple of years, BioCoRE selected students who appear to have been "hardcore pre-meds in disguise." Recognizing this issue as we talked to members of the first two cohorts of Scholars during events, we refined our application process by adding more information from outside sources (such as the departmental assessment items where students rated career goals on Likert scales) over the years, and this made a difference in terms of identifying students who had honest curiosity about the possibility of a lifetime career in scientific research.

Based on our program assessment, we learned that it is challenging to consistently identify a cohort of Duke first-year undergraduates who already have a clear-cut inclination toward a research career track. Evidence of this lies in the number of participants who chose non-research MD pathways upon completion of the program as well as the six BioCoRE Scholars who left the program before senior year, either because they changed their minds about the research career path or due to a leave of absence from school (Table 5). Many students can be identified with the curiosity and intelligence to be potential scientists, but only later will it become apparent whether they will be sufficiently drawn to research to pursue a PhD. Therefore, we conclude that programs like this could be even better if we increased mechanisms for lateral entry into the program by sophomores, juniors, and even seniors who suddenly realize that a science career is their desired future pathway. While many efforts continue to target the critical first 2 years of college, more programs like the NIH's Maximizing Access to Research Careers program are now aiming at and providing greater support to junior- and senior-year undergraduates who have shown interest and promise in biomedical research careers.

BioCoRE Scholar Outcomes

In May 2020, the fifth cohort of undergraduate BioCoRE Scholars graduated. Over the course of the program, 51 individuals participated in this program with at least 1 year of supported research. Forty-eight of these students graduated with a baccalaureate degree in at least one STEM field (obtained goal: 94%), two students graduated with non-STEM majors (public policy major with two STEM minors and an economics major), and one withdrew from the university due to medical issues. Therefore, the overall BioCoRE Scholar graduation rate was 98%, with most of Scholars either double majoring and/or completing a STEM minor. Three students participated in the program for 1 year or less before leaving the program, 11 students received 1 year of support before the program funding expired (IMSD programs no longer support undergraduates, and this resulted in a gap in our funding), and the remaining 37 students participated with funding for their research for 2–3 years. Forty-six (92%) of the Scholars completed their degrees in 4 years, three completed their degrees in 5 years, and one graduated in >5 years. The median time to baccalaureate degree completion for the Scholars was 4 years, while the average time to degree completion was 4.1 years; these figures were determined for each scholar via their matriculation and graduation dates by considering a Fall/Spring/Summer academic year as 1 year; we did not subtract leaves of absence or other time away from study from the total time, which was computed based upon calendar passing of time only. The training start time point was at the beginning of sophomore year for all trainees in the BioCoRE program, and the training end time point for the first four cohorts was their graduation or when they left the program; for the last cohort, the training end time point was the end of their junior year, because that is when our program funding was depleted (again, the program could not be renewed, because NIH no longer allows renewals for that program to support undergraduate training).

Aggregated information that we have about the next steps for the Scholars' careers and training are shown in Table 6. From these cohorts, 60% of the graduates moved into an immediately subsequent position that was research intensive. Obviously, for the 2020 graduates, the initial position (Table 6, column 2) and the current position (Table 6, column 3) are the same position. This is also true for graduates who went straight into PhD, MD, or MD/PhD programs. Twelve Scholars are currently enrolled in PhD programs. Another eight Scholars are applying or planning to apply to a PhD or MD/PhD program (currently working in research-intensive gap-year positions), while nine are currently MD candidates or in other health professions schools. This is a tremendous improvement over previous years. Indeed, before our implementation of the BioCoRE program, data from the institution's graduating senior surveys and alumni surveys showed that an average of only one student from a historically UR group per year continued to pursue a science PhD. At the time of this submission, other BioCoRE Scholars have entered the industrial or governmental workforce or are currently seeking employment or taking gap years without a clear plan; the latter phenomenon is mostly an unfortunate by-product of the COVID-19 pandemic disruption to our economic and education systems. The fraction of BioCoRE Scholars who intend to pursue an MD may reflect Duke's pre-med institutional history, influenced also by Duke's specialized advising devoted to pre-health tracks.

TABLE 6. Program outcomes: subsequent career and training steps for BioCoRE Scholars upon graduation from college: aggregated data for five classes of Scholars with graduation dates between 2016 and 2020, inclusive

Postgraduation: Type of position obtained	No. of Scholars in initial position of this type	% of Scholars in initial position of this type	No. of Scholars in current position of this type	% of Scholars in current position of this type
Research-intensive positions				
PhD candidate (biomedical, behavioral, or natural science)	4	8%	10	20%
MD/PhD candidate	2	4%	2	4%
Academic post-bac or master's research program	3	6%	0	0%
Other academic position (research intensive)	15	30%	7	14%
Government agency position (research intensive)	2	4%	0	0%
Industrial or NGO position (research intensive)	4	8%	6	12%
Non–research intensive positions				
MD, DO, DVM, or nursing graduate degree candidate	5	10%	9	18%
Other academic position (non–research intensive)	2	4%	1	2%
Government agency position (non-research)	2	4%	2	4%
Industrial or NGO position (non-research)	4	8%	6	12%
Unknown	6	12%	6	12%
Seeking employment	1	2%	1	2%

We were surprised by some BioCoRE Scholars choosing to take gap years after earning their undergraduate degrees. However, taking a gap year (or two) is now becoming a widespread trend among our recent graduates regardless of planned career path, race, or ethnicity. As an illustration, six of the BioCoRE Scholar graduates who are now in PhD programs first pursued a gap-year experience. Martin (2010), O'Reilly (2006), and Birch and Miller (2007) found that the gap year provides an opportunity to develop independence and certainty. It is important to note that some of the Scholars who pursued a gap year did so because they won a prestigious fellowship to study abroad for a set period of time, such as through the Fulbright Scholars program. We do not know all of the reasons why other BioCoRE scholars chose to pursue gap years, and future work could include determining why these individuals made this choice. We suggest that this new trend should be studied so that interventions could be implemented into the training program that might mitigate these issues. For example, we know that, in some cases, students' families sacrificed to help get them into and through college, and there may be a cultural expectation that they will pursue medicine and/or a strong drive to "give back" financially to the family. In cases where one reason for beginning graduate school is that students feel pressure from family to give back financially, then an intervention focused on discussing these options with family members may be viable. We hypothesize that another reason for the trend toward taking gap years is that colleges with highly selective admissions processes require intense effort, and a less stressful period in which to regroup before going into a potentially stressful graduate training is attractive to many students. Moreover, for some BioCoRE Scholars, an interest in research must be balanced by several considerations. Some students who become attracted to research in college might not feel that they have the top academic qualifications graduate programs are seeking, and additional research experience could be the best way to build toward a strong application to PhD programs. Birch and Miller (2007) reported that students with low academic marks are more likely to take a gap year. In the face of such headwinds against a research career direction, testing the waters with a laboratory experience is a good way to assess whether their attraction to research will be enough to compensate for such cultural expectations or financial considerations. Regardless of their reasons, a gap year (or two) is an attractive and rational next step for an increasing number of science graduates, and the research community should examine what is driving this trend.

Based on our program assessment, we learned that it is challenging to consistently identify a cohort of Duke first-year undergraduates who already have a clear-cut inclination toward a research career track. Evidence of this lies in the number of participants who chose non-research pathways, such as medical school or non-research industrial positions, upon completion of the program. Many students can be identified with the curiosity and intelligence to be potential scientists, but only later will it become apparent whether they will be sufficiently drawn to research to pursue a PhD. Therefore, we conclude that programs like this could be even better if we increased mechanisms for lateral entry into the program by sophomores, juniors, and even seniors who suddenly realize that a science career is their desired future pathway.

Implications for Translation to Other Settings or Institutions

Institutions with access to resources and funds can easily implement tangible items to increase UR involvement; however, there may be challenges between the cost–benefit ratios, as UR numbers may be minimal depending on the population. In cases where resources or institutional engagement is low, individual faculty can contribute to enhancing UR participation among their community in meaningful and informal methods. Many faculty include midsemester evaluations within their course, and similar to our chemistry survey, they can incorporate questions regarding careers and interest in research experiences. Understanding the landscape of your own classroom is both enlightening and informative, painting a primer for future actions. Furthermore, promotion of professional development opportunities (whether through the institution, professional conferences, etc.) can be easily disseminated in large settings. Students seeing faculty take an active interest in their success can break down invisible barriers between WR and UR groups. Because faculty are the sole initiators of CUREs within their classrooms, this is a mechanism by which they can single-handedly increase UR participation in research. Providing that innate research opportunity will bypass the hurdles some UR students encounter when trying to venture into research.

CONCLUSIONS

Our institutional case study compared undergraduates from WR and UR groups and revealed gaps between the groups in terms of their research experiences and career plans that persisted in the absence of an intervention. Because research experiences are a crucial component in the decision-making process for pursuing a research career and graduate study, the measured persisting experience gaps between UR and WR undergraduates in the general population comparison group at our institution were concerning. The BioCoRE strategy was to combine community building and professional development with hourly paid research for undergraduates that addressed the economic barriers for students who had work-study as part of their financial aid package. This strategy made learning through research positions financially competitive with other paid options like shelving books in the library or handing out towels at the gym. Our results clearly indicate that this strategy has been highly successful in allowing a more diverse group of undergraduates to participate in sustained laboratory research projects over multiple years. In addition, our data show that BioCoRE Scholars retain a higher self-reported interest in a career focused on scientific research throughout their college training when compared with the comparison group. Overall, results indicate that the set of activities developed in the BioCoRE program effectively acculturated UR students to the scientific mindset and opened their minds to the possibility of scientific research careers. By the time they graduated, undergraduate Scholars had gained substantial exposure to the research nature of the STEM PhD and the many career options available after the attainment of a PhD. The gaps between the WR and UR groups in terms of research experiences and career plans were closed by the implementation of the BioCoRE program. The BioCoRE program significantly sustained and supported Scholar interest in a lifetime career in scientific research when compared with comparison groups of similar peers. As a result, since the implementation of this program at the case study university, a larger number of graduating seniors who self-identify as belonging to UR groups have gone into PhD programs in STEM fields. The community of scholarship and programming described in this contribution can be adapted and tailored to other colleges and universities where faculty and administrators are hoping the achieve similar results.

RESEARCH LIMITATIONS

Selection bias is always a concern when data are collected via surveys; our response rates are high enough that we believe selection bias has been mitigated as much as possible. This work was conducted in an American educational context, and all participants were traditional undergraduate ages (18–25). Caution should be exercised in attempts to extrapolate these results to populations outside this age range, such as adult learners who may have more obligations such as full-time employment or childcare. The sample size of BioCoRE Scholars is relatively small. Though a larger sample size would be better, the sample size was limited, given that this was a pilot program with limited funding. Also, it is important to note that struggling in course work is well documented as one of the major reasons that undergraduates leave STEM majors (Seymour, 1992; Seymour and Hewitt, 1997). BioCoRE did not include academic support or require common course work as part of its programming. However, the social, research, and professional development components of BioCoRE likely would not have been as successful without a concurrent major revision to our institution's science curricula and academic support programs, such as work described separately for chemistry course pathways (Hall *et al.*, 2014; Canelas, 2015, 2016; Canelas *et al.*, 2017) and similar work in the biology department (Duncan *et al.*, 2016). So, a limitation of the work here is that we do not have evidence that the BioCoRE programming would have been as effective in the absence of the parallel science curriculum revisions. Practitioners and administrators should use caution in implementing cohort-based programs that attempt to improve retention in STEM research careers pathways in the absence of preceding or parallel attention to mitigating unintentional bias, filtering, or "weeding out" in foundational undergraduate science courses. Finally, while the data presented here demonstrate a collective impact of all components of the BioCoRE program on the students' interest in biosciences research careers, we do not have data to isolate individual components of the program and evaluate their separate impacts in a meaningful way.

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