JOURNAL of STEM OUTREACH

Vol. 6, Issue 1, April 2023

Outcomes and Lessons Learned from an Intensive Summer Undergraduate Research Program in Neuroscience

Manuella Oliveira-Yassa[1,2] and Chuansheng Chen[1,2,3]

[1]*Center for the Neurobiology of Learning and Memory,* [2]*School of Social Ecology, and* [3]*Department of Psychological Science, University of California, Irvine*

Keywords: STEM, Neuroscience, Summer, Undergraduate Research, NSF-REU, UC-HBCU, Attitudes Toward Science

Publication Date: April 24, 2023

DOI: https://doi.org/10.15695/jstem/v6i1.06

ABSTRACT: The United States continues to face racial/ethnic disparities in STEM degree attainment and workforce membership despite national efforts to address the disproportionately leaky STEM pipeline. One approach to tackling the underrepresentation of marginalized groups in STEM is to engage undergraduate students in intensive summer research programs that combine authentic, mentored laboratory research with cohort-wide professional development activities. Here, we report results of a research study evaluating the outcomes of an 8-week residential intensive summer research program focused on neuroscience. Evaluations revealed pre vs. post program improvement in science self-efficacy and identity as well as confidence in visualizing the career of a scientist. Additionally, perceived gains were observed in science-related skills as well as in thinking and working like a scientist. This work contributes to our understanding of how intensive research experiences shape knowledge, attitudes and practices related to STEM. Lessons learned here can be applied broadly to similar programs aiming to increase the diversity of the STEM workforce.

INTRODUCTION

The United States is experiencing a general shortage of individuals entering the STEM workforce, with available STEM jobs projected to outnumber the skilled workforce (Dall et al., 2013). In addition to the general shortage, despite our efforts as a nation, we have not been able to achieve STEM workforce diversity goals (Burke et al., 2022). This has been attributed to the failure of the "academic pipeline" to recruit and retain students from marginalized groups, a phenomenon often described as a "leaky pipeline" (Berryman, 1983). National data continue to show that the disparity in STEM degree attainment increases at each degree level. In 2019, Black individuals made up 14% of the U.S. population ages 20-34 but only 8.1% of doctoral degree recipients in science and engineering and Hispanic individuals made up 21% of the U.S. population but only 8.4% of doctoral degree recipients in science and engineering (Hussar et al., 2020). In contrast, White and Asian individuals made up 54.4% and 6.6% of the U.S. population and 69.1% and 10.6% of the awarded doctoral degrees in science and engineering. Black, Hispanic, American Indian, and Alaska Natives collectively represent 30% of the employed U.S. population but only 23% of the total STEM workforce (Burke et al., 2022).

Although Black and Hispanic students are just as likely to declare STEM majors as their White counterparts, they are more likely than White students to change majors or leave college, regardless of their socioeconomic status (Burke et al., 2022). Gender disparities also exist along the pipeline. In 2019, women earned 57% of all bachelor's degrees in the U.S., but they accounted for only 36% of the bachelor's degrees awarded in STEM fields (David & Amey, 2020). Thus, while the STEM pipeline is leaky for all individuals, it is particularly permeable for individuals from certain backgrounds.

To understand whether this racial/ethnic gap in degree attainment is unique to STEM disciplines, Riegle-Crumb and colleagues (Riegle-Crumb et al., 2019) explored patterns of departure in STEM and non-STEM areas for undergraduate students. Results suggest that indeed, this problem is unique to STEM fields. Not only are Black and Latino students who begin in STEM fields more likely than their White peers to switch majors, they are also more likely to leave college altogether and not earn a degree than those who begin in a non-STEM field. These persistent inequalities in STEM degree attainment form the basis for national efforts to address this problem.

Many types of programs exist to promote the success and persistence of individuals from marginalized groups in STEM fields (Tsui, 2007). Among the various approaches (curricular interventions, financial support, tutoring, career counseling and summer bridge programs), participation in authentic laboratory experiences has been shown to result in positive outcomes for undergraduate students (Tsui, 2007). Engaging undergraduate students in research can be achieved in various ways from course-based undergraduate research experiences (CUREs) in which a whole class engages in a project to address a research question, to individual supervised undergraduate research experiences in which students conduct research in laboratories under the guidance of a research mentor.

Many of these experiences are completed during the academic year concurrently with coursework. Still, there are individual and institutional challenges. For example, students who are employed may not have additional time to devote to extra-curricular research activities. Because most undergraduate research is unpaid, students who rely on employment to fund their undergraduate studies often must choose between volunteering in research or earning an income. In addition to the individual barriers, many institutions do not have the infrastructure to offer opportunities for engagement in research. Not surprisingly, universities with more research funding tend to have more research opportunities for undergraduate students (Kezar and Kinzie, 2006). Lastly, though many institutions may have active research in broad areas of science (e.g., biology, chemistry), they may not engage in the more focused research that is better aligned with the student's interests (e.g., neuroscience). To address these challenges, many look to the summer as an opportunity to offer immersive, financially supported research experiences.

The premise for engaging students in authentic hands-on research experiences is rooted in decades of research highlighting the impact of these experiences during the undergraduate years on the retention of students in STEM and their recruitment to graduate school (Gentile, 2017). The authentic research experiences that we consider here are distinct from course-based inquiry in three important ways: 1) they follow the apprenticeship model in which the student is mentored by a faculty member and often a graduate student; 2) they are conducted in research laboratories (as opposed to teaching laboratories) using methods and tools that are typically used by researchers in that field and they engage in inquiry that results in genuine contributions to the field; and 3) they are immersive, multi-week experiences (Hunter et al., 2010). These types of experiences are thought not only to equip students with the content knowledge and methodological skills necessary for success in research but have also been known to correlate with integration into the sciences and improved attitudes toward science, all of which have been shown to impact achievement and persistence in STEM (Estrada et al., 2011; Lent et al., 1994). Participation also can help students to clarify their post-undergraduate degree plans (Hunter et al., 2010). Participation in research experiences has been shown to be particularly impactful for individuals from marginalized backgrounds; thus, these programs have become a valuable avenue for broadening participation in STEM (Nagda et al., 1998).

To assess the impact of these research experiences, Hernandez and colleagues (Hernandez et al., 2018) conducted a longitudinal study across 29 U.S. colleges to compare outcomes of primarily Black/African American and Hispanic/Latino students who participated in undergraduate research experiences to similar students who had no research experience. They found that those who participated in research were more likely to graduate with a science-related bachelor's degree, matriculate in a science-related graduate program and remain in the science workforce six years after obtaining their bachelor's degree. Importantly, these results were observed only in students who were mentored by faculty and engaged in ten or more hours of research per week over two or more semesters or summers (Hernandez et al., 2018). Perceptions of long-term outcomes from participation in an undergraduate summer research experiences program were evaluated by Prince and colleagues (Prince et al., 2022) who found that 59% of students felt that the program influenced their career goals. Importantly, 61.5% endorsed having maintained contact with their former mentor after the program. Despite the low response rate (44%), this study and others (Howell et al., 2019; Jin et al., 2022) suggests that summer undergraduate research experiences programs can have positive long-term impacts on student career choices.

Results from a 2003 survey of a nationally representative sample of individuals who had received bachelor's degrees in STEM shed light on the specific mechanisms of impact on student outcomes. Specifically, participation in undergraduate research was associated with increased understanding of how to conduct a research project, confidence in research skills and awareness of what graduate school is like. Additionally, participation may also clarify interests in STEM careers and increase intent to pursue a Ph.D. These effects were strongest among Hispanic/Latino individuals and weakest among non-Hispanic Whites (Russell et al., 2007).

The purpose of the current study was to examine the impact of participating in an immersive summer research experience in neuroscience on undergraduate student science-related outcomes. The Irvine Summer Institute in Neuroscience for undergraduates is a program based at the University of California, Irvine's Center for the Neurobiology of Learning and Memory, jointly funded by the National Science Foundation Research Experiences for Undergraduates Program (NSF-REU), the Department of Defense Awards to Stimulate Undergraduate Research Experiences (DoD-ASSURE) Program and the University of California - Historically Black Colleges and Universities (UC-HBCU) Initiative. The study addresses the following research questions:

1. Does participation in the summer research program impact student knowledge related to science, the path to a PhD and the life of a career scientist?
2. Does participation in the summer research program impact student attitudes toward science such as science identity and self-efficacy?
3. Does participation in the summer research program impact student intended behavior regarding participating in future research and pursuing a PhD?

Additionally, we aimed to conduct a formative evaluation of the student experience and satisfaction to inform improvement efforts for the current program and to generate insights and lessons learned that can be applied to similar programs.

METHODS

Research Setting. The Irvine Summer Institute in Neuroscience Program was founded in 2021 as an 8-week long residential research program at the University of California, Irvine's Center for the Neurobiology of Learning and Memory. The program has trained two cohorts of students, with the 2021 program taking place remotely and the 2022 program representing the first in-person session. The program's activities are designed to target the spectrum of competencies that are necessary for success in science (Gammie, 2015) in support of the program's overarching goals. These are: (1) to increase the number of undergraduate students, particularly women, students from underrepresented ethnic/racial groups, students with disabilities, and first-generation college students who pursue degrees in neuroscience and biomedical research; (2) to grow and diversify the future pool of students applying to advanced degree programs in neuroscience and biomedical fields; and (3) to increase the diversity of the workforce in neuroscience and biomedical research.

Students in the program conduct research under the mentorship of faculty, graduate students, and postdoctoral fellows. They are expected to spend much of their time working on their research projects with their laboratory

Hour/Day	MON	Tue	Wed	Thu	Fri	Sat	Sun
9AM	Lab	Lab	Lab	Lab	Lab	Free (optional day-trips)	Free (optional day-trips)
10AM							
11AM	Office Hour with Program Director	Seminar	Journal Club	Prof Dev or Methods/ Workshop	Social Hour		
12PM	Lab	Lab	Lab	Lab	Lab		
1PM							
2PM							
3PM							
4PM							

Figure 1. Program week-at-a-glance. Sample weekly schedule for program showing daily cohort-wide sessions.

teams. This includes individual meetings with the faculty mentor and other team members, lab meetings, literature reviews and independent work. Laboratories are selected for participation based on faculty interest, availability of the faculty and graduate student mentors during the summer and faculty's commitment to the program's overarching goals. Student-mentor matching is completed before the students arrive on campus. Students are provided with a list and description of all the participating labs and are asked to rank their top five based on topics of interest. All students and all faculty mentors participate in a virtual (on Zoom) meet and greet session where each student meets with each of their top five faculty for ten minutes in breakout rooms. After this session, students select their top three faculty and faculty select their top three students. Matches are then made to maximize the overlap in the "top three" lists.

In addition to their laboratory work, students also are required to attend one cohort-wide meeting per day. All daily meetings are led by the program director and include a group check-in at the beginning of the session. Daily meetings include faculty-led seminars, journal club sessions, panels, neuroscience methods workshops, professional development opportunities and social activities (see Figure 1 for a week-at-a-glance summary). Broadly, the daily cohort-wide meetings are intended to standardize the exposure and experience of the students so that their knowledge is not as dependent on their laboratory placement and their individual research projects. Many of the professional development and journal club activities are based on the Entering Research curriculum (Branchaw, Janet et al., 2020). A description of each component is included below.

Office Hours with the Program Director are designed to provide an opportunity for students to interact with each other and with the program director in an unstructured format. Students use this time to discuss concerns regarding the program, laboratory work, housing, etc. The program director uses this time to gain real-time informal feedback about the program activities from students and to address any socio-emotional student needs that may not surface during scheduled structured sessions. The session takes place in the conference room, with access to the director's office for private conversations.

Seminars are led by faculty and are opportunities for students to gain breadth in their neuroscience knowledge. Seminars ensure that all students are exposed to important neuroscience areas and concepts such that their knowledge extends beyond the specialty of their laboratory placement. Faculty are asked to include in their scientific seminars a brief discussion of their path which displays to the students the variety of paths that can lead to a career in neuroscience research.

Journal Club sessions are led by graduate student mentors and are designed to introduce students to the anatomy of a research article and to teach them how to read scholarly work. During the first journal club, students learn about the different types of peer-reviewed articles, how to find scholarly work and how to navigate the articles. During weeks 2-8, students read one article per week on a range of neuroscience topics. By engaging students in reading, dissecting, and discussing the strengths and limitations of the articles, the program aims to help students to sharpen their critical thinking skills and communication skills and to strengthen their knowledge of research design, neuroscience methods, and data analysis.

Methods Workshops are designed to broaden student exposure to the many cutting-edge methods that are used in neuroscience research that may or may not be used in their own laboratory research. Methods workshops take place in laboratories and core facilities and provide an opportunity for students to experience a variety of laboratory settings and contexts.

Professional Development Workshops aim to train students in skills such as developing a CV, requesting letters of recommendation, preparing a scientific poster, and making an oral presentation. These workshops prepare students to apply to graduate school and equip them with the "soft" skills necessary for a career in science research.

Social Hours are dedicated to activities that build cohort camaraderie and provide opportunities for students to socially engage with graduate students and sometimes faculty. Activities during these sessions include designing the cohort shirt, tie-dying the shirts once they are printed, and socializing with faculty during an ice cream social.

Weekend activities are not planned or funded by the program. Student-organized activities include beach days, day-trips to Los Angeles, hikes, and a visit to Disneyland.

Additional Online Training as required by university and NSF is completed through the university's online learning center. All students complete the responsible conduct of research (RCR) training. Additionally, students complete training specific to their laboratory research including sessions on human research protections, animal care and use and biosafety.

The program culminates in a half-day research symposium where students present their work in elevator pitch and scientific poster formats. The research symposium is attended by participating lab members as well as other university scholars, community members and even some parents and family members. The research symposium also features a keynote lecture by a faculty member.

Program participants receive room and board accommodations on campus as well as a weekly stipend of $650 and travel allowance of up to $900 to cover travel to and from the program.

Participants. The Irvine Summer Institute in Neuroscience is open to undergraduate students who have finished their first year in college, are U.S. Citizens and have a GPA of 3.0 or higher. While the slots funded by NSF are open to students from any institution, 10 (those funded by UC Office of the President) are designated for students from Historically Black Colleges/Universities (HBCUs). The online application is split into two phases. The initial phase requests demographic information, a resume or CV, college transcript and brief (250-word) responses to three prompts: 1) Describe your personal research interests and why you are interested in participating in this program; 2) Share a difficulty in your life that you have overcome and what you learned from it; 3) Have you participated in community outreach activities? If yes, please provide examples. Phase 1 applications were reviewed, and half were invited to advance to phase 2 which included a request for two letters of recommendation.

Consistent with the program's overarching goal to broaden participation in neuroscience, women, students with disabilities, first generation college students and those from racial/ethnic backgrounds underrepresented in science are particularly encouraged to apply. The program's outreach and recruitment campaign includes social media engagement as well as collaboration with faculty and administrators at HBCUs, Minority Serving Institutions and community colleges. The program hosts two virtual information sessions during the application period that offer a preview of the program and an opportunity for prospective students to ask questions.

Data Collection. This study was determined to be exempt based on the University of California, Irvine IRB Exempt Self-Determination Tool, Category 2. Study participants were recruited via email from the pool of 2022 Summer

Table 1. *Demographics.*

	N
Number of undergraduate student participants in program (N)	22
Number of completed survey responses (n)	21
Response Rate	95%
Total number URM	20 (95%)
Number with GPA 3.6-4.0 (%)	16 (76%)
Number with GPA 3.0-3.59 (%)	5(24%)

Note. URM refers to students from racial/ethnic backgrounds underrepresented in science (Black/African American, Hispanic/Latino, American Indian, Alaska Natives, Pacific Islander, Native Hawaiian).

Institute in Neuroscience students. Participation in the research study was voluntary and those who chose to participate (*N*=21) provided informed consent before completing the surveys. Data for this study was collected using web-based, anonymous evaluations completed outside of formal program sessions. The surveys were linked using participant-generated codes to allow for paired comparisons.

Participants were asked to complete three surveys. The pre-and post-program evaluations (conducted the week before the start of the program and at the conclusion of the program, respectively) included modified versions of two validated surveys that have been used extensively in the evaluation of summer research programs, the Undergraduate Research Student Self-Assessment (URSSA) (Hunter et al., 2009) and the Survey of Undergraduate Research Experiences (SURE) (Lopatto, 2004). The URSAA measures student self-reported gains in science-related skills and knowledge, science attitudes, and preparation for graduate school. Averages of composite variables have been used to track changes between years and make comparisons between programs. Reliability for these variables as measured by Cronbach's alpha are between 0.83 and 0.92 (Weston and Laursen, 2015).

The SURE additionally allows for evaluation of pre-post changes in science attitudes. Validation studies of this survey with over 3,000 undergraduate students in over 50 universities has revealed high reliability indicated by a Cronbach's alpha of 0.94 (Lopatto, 2004, 2007).

A mid-program survey was additionally administered to measure whether the program was being implemented as planned and to understand student satisfaction with the program at the midpoint. Students were asked about the frequency with which they were communicating with their mentors and were asked to provide recommendations regarding improvements to the program. This evaluation enabled the program director to make programmatic changes and to address any issues related to the cohort-wide activities, laboratory work, mentorship, housing, etc.

From a total of 22 undergraduate students in the program, 21 completed the survey for a response rate of 95%. Of these students, 20 (95%) self-identified as being from one of the racial/ethnic groups that are underrepresented in science, with 76% indicating that their undergraduate GPA was between 3.6 and 4.0 and the remaining 24% indicating a GPA between 3.0-3.59 (see Table 1 for demographic information). Note that due to the small number of males in the program, gender identity was not asked in the survey to protect the anonymity of the participant responses.

Data Analysis. Data was analyzed using SPSS Statistics software. Pre vs. post comparisons were conducted using paired t-tests. Variables were evaluated for normality using the D'Agostino-Pearson's K^2 test. For those variables that did not pass the normality test (using a threshold of alpha = .05), a Wilcoxon test is reported.

RESULTS

Changes in Skills and Knowledge. To understand the impact of participating in the program on student knowledge, students were asked questions related to their knowledge of the path to a PhD and life of a career scientist. Analysis of responses on pre- and post- surveys reveals an increase in student confidence in visualizing a career scientist. Students were asked to indicate, on a scale of 1 (I don't have a clue as to what they are talking about) to 5 (I have a very clear idea what they are talking about) in response to the prompt "When someone discusses a 'career scientist', how easy is it for you to visualize a career of that sort". A paired-samples t-test was conducted to compare confidence in visualizing a career scientist before and after participation in the program. There was a statistically significant increase comparing scores before the program (M=3.62, SD=1.07) and after the program (M=4.24, SD=0.70) ($t(20)$=2.15, p=.04). The effect size for this analysis (d=0.47) reflects a small to moderate effect based on Cohen's (1988) conventions, reflecting a potential practical significance of this finding (see Figure 2).

Perceived learning gains in skills as well as thinking and working like a scientist were evaluated in the post-program survey. Students were asked to reflect on how much they gained in various areas because of their participation in the summer program (responses were rated on a scale from 1(no gains) to 5(great gain) and are shown in Figures 3a and 3b).

Changes in Attitudes. To measure changes in student attitudes toward science, students were asked questions related to their science identity and self-efficacy. Analysis of responses on pre- and post- surveys reveals improvement in science identity and self-efficacy.

Science Identity. Students were asked to rank the extent to which they agreed or disagreed with the following statements: 'I see myself as a science person' and 'Others see me as a science person'. Responses were on a scale of 1 (strongly agree) to 4 (strongly disagree) and were reverse coded during analysis for clarity such that larger numbers

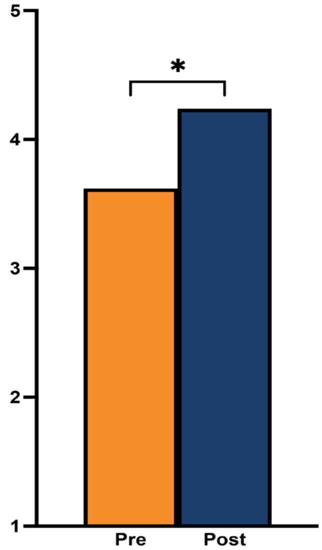

Figure 2. Students' confidence in visualizing career of a scientist pre- vs. post-participation in the program. *p<.05.

represent more positive attitudes (see Figure 4).

The extent to which students agreed or disagreed with the statement "I see myself as a science person" increased from before the program (*M*=3.71, *SD*=0.46) to after the program (*M*=3.86, *SD*=0.36). A paired-samples *t*-test revealed that this difference was not statistically significant at an alpha level of 0.05; $t(20)=1.83$, $p=.08$. The effect size for this finding ($d=0.4$) reflects a small to moderate effect, suggesting that though this difference did not reach statistical significance, it may have practical significance. A test of normality using the D'Agostino-Pearson's K^2 test revealed that this variable is not normally distributed. A Wilcoxon test was additionally conducted to test this difference, also resulting in nonsignificant difference.

The extent to which students agreed or disagreed with the statement "Others see me as a science person" increased from before the program (*M*=3.48, *SD*=0.51) to after the program (*M*=3.76, *SD*=0.44). A paired-samples *t*-test revealed that this difference was statistically significant; $t(20)=2.33$, $p=.03$. The effect size for this finding ($d=0.51$) which reflects a moderate effect.

Science Self-Efficacy. Students were asked to rank the degree to which they agree or disagree with the following statements: 'I am confident I can do an excellent job in science research' and 'I am good at science'. Responses were on a scale of 1 (strongly agree) to 4 (strongly disagree) and were reverse coded during analysis for clarity such that larger numbers represent more positive attitudes.(see Figure 4).

The extent to which students agreed or disagreed with the statement 'I am confident I can do an excellent job in science research' increased from before the program (*M*=3.43, *SD*=0.51) to after the program (*M*=3.81, *SD*=0.40). A paired-samples *t*-test revealed that this difference was statistically significant $t(20)=3.0$, $p=.008$. The effect size for this finding ($d=.65$) reflects a moderate to large effect.

The extent to which students agreed or disagreed with the statement 'I am good at science' increased from before the program (*M*=3.24, *SD*=0.44) to after the program (*M*=3.67, *SD*=0.48). A paired-samples *t*-test revealed that this difference was statistically significant; $t(20)=3.9$, p=.001. The effect size of this finding ($d=.85$) reflects a large effect. A test of normality using the D'Agostino-Pearson's K^2 test revealed that this variable is not normally distributed. A Wilcoxon matched pairs signed rank test was additionally conducted to test this difference. Results of that analysis indicate that there was a significant difference ($p<.001$) in responses to the statement 'I am good at science' from before and after the program.

Perceived changes in science self-efficacy including confidence in ability to do research and to contribute to science as well as confidence in ability to do well in future science courses was measured in the post-program survey. Responses were on a scale from 1(no gains) to 5(great gains). 100% of the survey respondents reported gains in all four items (*M*=4.7, *SD*=0.57).

Most of the students (95%) endorsed feeling more prepared to conduct research, more comfortable reading and understanding scientific papers, more confident in their career prospects and more confident talking about science. Changes were not seen in enjoyment of science $t(20)=0.44$, $p=0.67$.

Changes in Behavioral Intent. Perceived changes in behavioral intent to continue research or pursue matriculation in graduate school were evaluated during the post-program survey. Compared to their intentions before doing research, all students endorsed being more likely to enroll in a PhD program in science, mathematics, or engineering. Most students (95%) endorsed being more likely to look for research opportunities on their own, more likely to apply to the University of California, Irvine, and more likely to apply to one of the campuses in the University of California system for graduate school.

Students were asked how, if at all, their summer experience changed their perceptions of a career in science or plans for their future. Fifteen of 21 students responded to this free-answer question. Some themes that emerged from their responses included increased interest, excitement, confidence, and motivation to pursue a PhD and improved clarity regarding the process of applying to graduate school and the work of a PhD-level scientist (individual responses can be found in Table 2).

Satisfaction. Participant satisfaction with the program was evaluated in the mid- and post-program surveys. Satisfac-

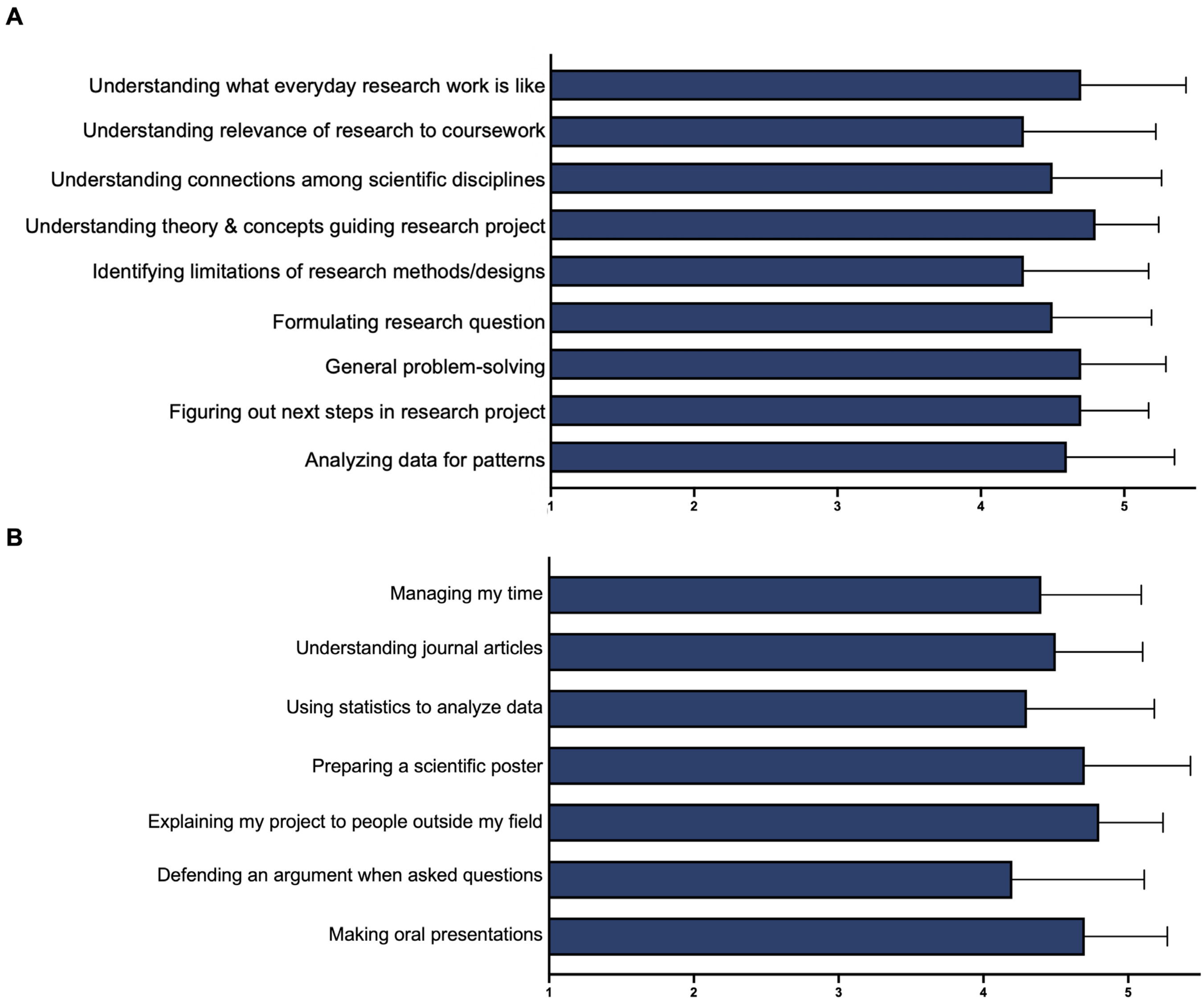

Figure 3. Gains in thinking and working like a scientist and gains in skills. Students were asked to reflect on how much they gained in various areas because of their participation in the summer program. Perceived gains in thinking and working like a scientist (A) and perceived gains in skills (B) are shown. Responses were rated on a scale from 1(no gains) to 5 (great gains).

tion was high at both timepoints with all students responding positively when asked about their satisfaction with the program. All participants also indicated that they would recommend the program to a friend in the post-program survey. Participants were asked to name the single best part of the summer experience. Nineteen of 21 students responded to this free-answer question. Some themes that emerged included mentorship and relationships that were formed, the skills that were gained, and having the opportunity to present their work at the end of the summer (individual responses are included in Table 3).

Process Evaluation Results. To measure whether the program was being implemented as planned, a process evaluation was conducted in the mid-program evaluation. This evaluation guided both immediate and future programmatic changes and allowed the program director to address issues and concerns. Students were asked about the frequency of their communication with someone from their lab group, with 95% indicating daily communication (the remaining participants indicating that they communicated at least twice per week). Students were additionally asked to provide comments or suggestions regarding the program. A few concerns about program logistics were raised, including those regarding housing, dining hall and stipend disbursement schedule.

Program participants were housed on campus in undergraduate dorms, a process facilitated and managed by the campus. The program's participants were split in their housing assignments into two housing communities that differed in important ways including their age and available amenities. The students expressed that they felt this was unfair and that being housed together would have improved cohort bonding. Unfortunately, this was not a concern that could be

Table 2. *Changes in perception of career in science or plans for future as result of summer experience.*

Individual Participant Responses
This summer made me more interested in pursuing a PhD.
As a result of my summer experience, I now know that a career in science is something I can definitely see myself doing, and I plan to pursue a Ph.D. after college because of this!
I was a little hesitant about applying to grad school, especially right away out of senior year. I also didn't know where to start. This summer helped to not only really solidify my plans and get me excited about grad school, but it also showed me how to start so that the process is much less daunting.
I did not imagine I would want to pursue a career in research or as a scientist but now I do.
It enhanced it! I have gained lots of confidence and am excited for a science-led career!
It showed me just how vast and undiscovered the world of science is. I can be more than just a doctor if that is something that I wanted to do. I thought that it was one or the other but that was not the case.
It made me more confident that I am choosing the right path for myself.
It allowed me the confidence to pursue research.
I probably won't do a PhD in psychology (instead, in neuroscience).
Lab work is so broad you never know what a lab will be like. Which is a good thing.
This experience solidified my decision to attend Grad School and pursue a PHD.
It made [me] realize that you can help patients indirectly or directly without going to medical school and I've learned that PhD is my true calling.
This summer taught me that I need to take the time to actually gain experience in both the research and medical field.
This summer experience has solidified my interests in a science career and created an interest in going to UCI for my PhD.
My experience helped strengthen my love for science. It also helped me decide what journey I want to take to get to my career in science and medicine.

Note. Students were asked to comment on how, if at all, their summer experience changed their perceptions of a career in science or plans for their future. 15/21 students responded to this free -answer questions. Table shows individual responses.

addressed mid-program. However, we include a discussion of the importance of housing decisions in the next section as well as recommendations for managing such issues.

Participants raised concerns about long wait times at the dining halls during lunch and that this was interfering with their time in lab. In response, the program director met with the campus dining team and the concern was addressed. A relevant discussion about decisions regarding meal allowance versus dining hall access is included in the following section.

Student stipends were planned to be disbursed every two weeks. Though the program planned and began the process of approving students to be paid by the institution weeks in advance, delays in the process resulted in some students not receiving their stipends according to the schedule, which was raised as a concern. Recommendations for stipend disbursements are included in the following section.

DISCUSSION

The health of the US economy and our global status as leaders in innovation and discovery in science and technology depend on the quality of our STEM workforce. Abundant evidence has shown that in order to achieve excellence in the STEM workforce, we must have diverse teams working together and capitalizing on innovative ideas and perspectives (Hong and Page, 2004). Closing the gaps in STEM workforce participation has impact not only at the macro level in terms of economic growth and global status but also the micro level in terms of individual benefits.

Addressing the disproportionately leaky pipeline to the STEM workforce requires a holistic, intentional, and data-driven approach. Engaging undergraduate students in laboratory research is a valuable way to broaden participation in science. Participation in research has been shown to result in gains in the following areas: Knowledge (thinking and working like a scientist, skills, preparation for graduate school/career, clarification of career/educational goals), Attitudes (science-related self-efficacy and identity, enjoyment), and Practice (intent to pursue graduate studies, matriculation in graduate programs).

The current study examined the impact of participation in an 8-week intensive research program in these areas. Student gains were noted in thinking and working like a scientist, science-related skills, knowledge of the life of a career scientist, science self-efficacy, science identity and intent to pursue a PhD. Qualitative data further help to contextualize results and enrich our understanding of the student experience.

Knowledge. Immersion in real science laboratories and interaction with real scientists foster growth in many areas. Perhaps most obvious is growth in knowledge of the path to the PhD, thinking and working like a scientist and science-related skills. Many of these areas are directly addressed in the laboratory by the faculty or graduate student mentor and others are addressed in the cohort-wide activities. Some of the gains that were observed, for example, "understanding what everyday research work is like," would be challenging to teach without the immersive and multi-week nature of the program. Other observed gains, for example, "preparing a scientific poster," "making oral presentations"

Table 3. *Participant perception of single best part of summer experience.*

Individual Participant Responses
There are so many, but I would have to say the poster presentation. It was nice to be able to talk to people and have questions asked about what I have been working on all summer. I liked having people be interested in my research.
Workshops to better my skills
Feeling accepted and a part of the science research community!
Being able to run the experimental tests on my cohort of rats and then analyze the data
The connections I built with my lab mentor and other lab members
The people I met, relationships I built, and the science I did :) sorry that was three lol.
Working in the lab and attaining valuable laboratory skills
Connecting and Networking
poster presentation
The relationships formed
Presenting a paper at a lab meeting
The friends I made.
The love [the program director] had for us all!
The group outings we would have on the weekends
Making new connections
Being around the people I was with and getting to enjoy the California life.
Presenting the hard work I have done at the symposium with people that I love
My mentor
Getting to know faculty and other students

Note. Students were asked to comment on what they thought was the single best part of their summer experience. 19/21 participants responded to this free-answer question. Table shows individual partiicpant responses.

and "understanding journal articles" are likely more closely tied to specific cohort-wide activities.

The daily group activities that supplement the laboratory work are critical to the program for various reasons. First, the cohort-wide activities enable the development of a community, the importance of which we describe below. Second, given the interdisciplinary nature of neuroscience and the heterogeneity in laboratory methods, structure and mentorship, the laboratory experiences vary widely from student to student. The group meetings ensure some standardization in the topics and skills that the students learn. Third, it is during these meetings that students learn how to navigate the challenges of beginning research.

Although some students may experience a smooth transition into research, others, particularly students who have never been exposed to research and those who are first generation college students, experience a culture shock, and often are left to learn crucial information on their own. By employing the Entering Research curriculum (Branchaw, 2020), we intentionally addressed these often-untaught skills to foster a smooth transition for all students. Activities were directly tied to learning objectives that aligned with overall goals of the program and included areas such as research comprehension, communication skills, practical research skills, research ethics, researcher identity, researcher confidence and independence, equity and inclusion awareness and skills, and professional and career development skills.

Importantly, the activities are designed to progress logically through the 8-week experience. For example, we began with activities that encourage students to learn about other members of the laboratory, establish healthy communication with their mentors and learn how to read a scholarly journal article. Activities to teach students how to develop their CV and communicate their research through a research story and a scientific poster were taught later in the program. The program also emphasizes practical skills such as how to navigate conversations about authorship, request letters of recommendation, and manage conflict.

Attitudes. Because psychological factors such as attitudes toward science have been found to predict academic motivation, achievement, persistence, and career choice, they have become targets for interventions aiming to address the leaky pipeline (Estrada et al., 2016; Hunter et al., 2009; Lent et al., 1994). Our findings suggest that participating in an intensive research experience can improve science self-efficacy and identity.

The changes in science self-efficacy and science identity observed may serve as mediators in the relation between participation in undergraduate research experiences and persistence in STEM. Participants' pre-program scores on science self-efficacy and science identity were positive. This was expected since these students chose to participate in a summer-long research program. Nevertheless, improvement was still observed in these measures, suggesting the beneficial effects of such a program even on students with already positive science attitudes.

Self-efficacy, or "the belief in one's capabilities to organize and execute courses of action required to produce given attainments" (Bandura, 1977), has been extensively studied, and has been found to predict student interest, goals and persistence to pursue STEM careers (Burgoon et al., 2012; Komarraju and Nadler, 2013; Pajares and Graham, 1999; Pajares and Urdan, 2005; Pintrich and DeGroot, 1990). Social cognitive career theory (SCCT), developed by Lent and colleagues (Lent et al., 1994) based on Bandura's work, posits that self-efficacy and outcome expectations lead to career interests that, in turn, lead to career choices. Self-efficacy is thought to be an important factor in predicting behavior of students as they develop their career plans (Gainor and Lent, 1998). SCCT has been used as a framework to study self-efficacy as it relates to persistence and performance in STEM. For example, Lent et al. found evidence for a relation between self-efficacy and academic achievement, showing that students who reported high self-efficacy persisted longer in technical and/or science majors over the following year than those with low self-efficacy (Lent et al., 1984). SCCT has been used to understand the career development process

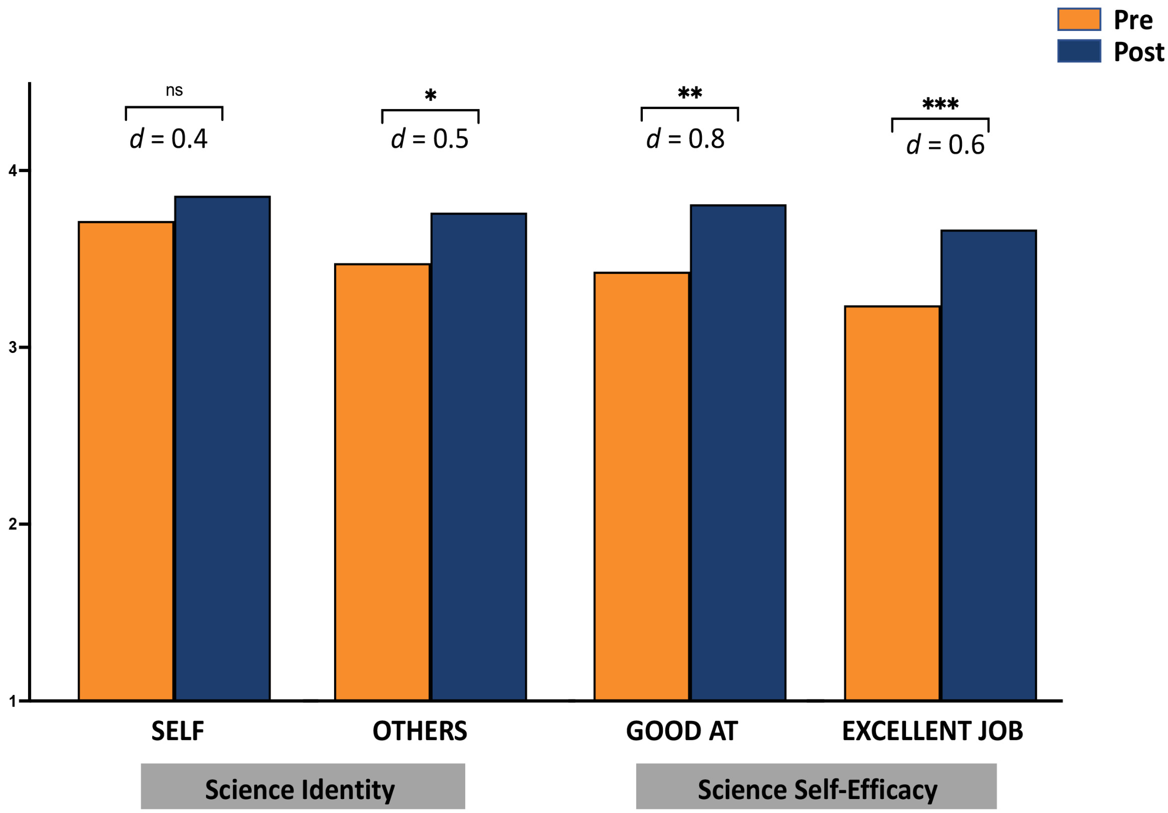

Figure 4. Student attitudes toward science pre- vs. post-participation in the program. Students were asked to rank on a scale of 1(strongly agree) to 4(strongly disagree) the extent to which they agree with the following statements: I see myself as a science person, others see me as a science person, I am good at science, and I am confident I can do an excellent job in research. *p<.05, **p<.001, ***p<.001.

across diverse populations as it accounts for the background and contextual factors that contribute to career development (Byars-Winston et al., 2010; Flores et al., 2010; Gainor and Lent, 1998). Studies have identified increasing self-efficacy as a way to increase achievement and persistence in STEM (Ballen et al., 2017; Gainor and Lent, 1998), and have thus identified self-efficacy as a target for interventions aimed at patching the leaky pipeline. Environmental support, in the form of receiving financial or social support, has been shown to positively predict self-efficacy. The environmental support that the students experienced in this program (financial and social) may have led to the increase in self-efficacy reported. Using the SCCT as a framework, we may consider the possibility that self-efficacy may serve as a mediator in the relation between participation in undergraduate research experiences and persistence in STEM.

Whereas science self-efficacy refers to the student's belief in their ability to complete a task (e.g., "I am confident I can do an excellent job in science research"), science identity refers to the student's view of themselves as a "science person" and whether they perceive others to view them as a "science person". The development of science identity is thought to involve a negotiation between differentiation and fitting in with the cultural norms of one's community including one's family, peers, and scientists. Interestingly, studies suggest that students see school science and 'real' science as distinct from one another, which may have implications in the development of their science identity (Zhai et al., 2014). Having the opportunity to engage in 'real' science might then enhance the student's development of their science identity. Development of science identity can also be influenced by misalignment between a student's academic identity (e.g., student, scientist) and their personal identity (e.g., woman, Hispanic), highlighting the importance of creating inclusive environments where students can fully express multiple identities.

Practice. Although we do not yet have data on participants' science-related behaviors post-program, we did measure their intent to seek more research opportunities and apply to graduate school. Additionally, we were able to gain insight into changes in intent to engage in science-related behaviors from qualitative data. Overall, the data suggest a beneficial effect of participating in the program on student intent to continue research and pursue a doctoral degree. We will continue to track participants every 6 months using surveys and one-on-one meetings with the program director to evaluate post-program behavior including undergraduate graduation, further participation in research, presentation at conferences, publications, application to and enrollment in graduate school, etc.

Study Limitations. The current study is limited by three major factors: lack of a comparison group, small sample size and selection bias. Our hope is to conduct another evaluation using random assignment and a larger participant pool. Selection bias is harder to address because study participants are recruited from a program to which they applied and were selected through a competitive process. Results seen here may not generalize to undergraduates broadly but may be more relevant for students who display at least a moderate level of motivation to pursue a career in STEM.

Lessons Learned and Recommendations. Data from formal and informal program evaluations are used by the program director to guide changes and improvements to the program. In this section, we include lessons learned and recommendations that may be useful for others who are engaged in the design, implementation, and evaluation of similar programs. Guided by data from the program evaluations, the program aims to make three structural changes in future years. (1) The daily cohort-wide meetings will change from 11 am-12 pm to 9-10 am. Though the 11 am cohort-wide meetings worked well for the previous year's program in the virtual format, students in this cohort found it to be disruptive of their laboratory work especially when conducting experiments or performing assays that required longer blocks of uninterrupted work. (2) The meal plan offering will be reconsidered to offer students an opportunity to eat in the dining hall for breakfast and dinner but allow them to purchase food from other locations for lunch. Students found that while they enjoyed the food in the dining hall, it was practically challenging to go to the dining hall during lunch because it was located across campus from many of the labs. (3) The planning of weekend social activities will be facilitated to enhance their availability and accessibility. Though weekends are intentionally not planned with program-wide sponsored activities, student feedback suggests that support with planning these optional activities would enhance their experience.

Below we offer a few broad recommendations for others who engage in similar work.

1. ***Design with Intention***. Program design is an orchestration of many moving parts and requires many decisions regarding who, what, where, when, and why. Intentional design begins by thinking about the program outcomes and goals. Programs are made up of many seemingly small decisions and considering the objectives when making those decisions will ensure that the program activities are aligned with its overarching goals.
2. ***Plan Ahead.*** Summer program management is a year-around task and planning for the following summer begins almost immediately after the conclusion of the program. Given the large number of components that need to be coordinated, planning is critical to the success of the program and satisfaction of the student participants. It is important to plan with campus staff, especially the financial administration team who will support the program by processing stipends and travel reimbursements. Much of the paperwork can be completed before the students arrive to avoid delays.
3. ***Communicate Effectively.*** Constant and explicit communication with the students and mentors is critical to the success of the program. Outlining expectations, providing schedules, and communicating concerns promote the success of all students. We recommend having one place where all program-related information can be found and where students can contribute resources (e.g., Google drive). Additionally, we recommend having a messaging app such as Slack for daily communication among the students and between the students and program director. Setting this up before the students arrive on campus fosters early cohort building by encouraging students to get to know each other before meeting in person. We also recommend providing guidance surrounding communication methods especially regarding emergencies. Communication is perhaps most important when concerns are raised. We found that even when we were not able to solve the problem, providing a safe space where students could voice their concerns was crucial.
4. ***Build Community***. The social components of a program are perhaps the most overlooked in program planning but are essential to the success of the program. Social activities on and off campus foster connections among the students and between students, mentors, faculty, and the program director. We recommend planning social activities with the same level of intention as the other activities in the program and considering whether these activities are inclusive and accessible by all members of the program community.

In 2017, the National Academy of Sciences Committee on Strengthening Research Experiences for Undergraduate STEM Students surveyed the current state of undergraduate research experiences in the U.S., the results of which are published in the book *Undergraduate Research Experiences for STEM Students: Successes, Challenges and Opportunities*. Among several conclusions and recommendations, the committee encouraged undergraduate research program designers and implementers to make evaluation data accessible so that others may "build upon knowledge gained from other [programs]" (National Academies of Sciences and Medicine, 2017). Our goal here was to share information about the structure of our program, data on student outcomes, and lessons learned, so that others may benefit from our experience. Our results add to the growing body of evidence supporting the benefits of participating in undergraduate research on student science-related outcomes.

AUTHOR INFORMATION

Corresponding Author

Manuella Oliveira-Yassa, Center for the Neurobiology of Learning and Memory, University of California, Irvine. 309 Qureshey Research Lab Irvine, CA 92697-3800. Email: manuella.yassa@uci.edu

Author Contributions

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

ACKNOWLEDGMENTS

We thank Dr. Nancy Guerra for her edits to the manuscript. We would also like to thank the faculty, students and staff who make this program possible including Dr. Autumn Ivy for her partnership in the UC-HBCU program.

FUNDING SOURCES

The program is financially supported by a grant (2050194) from the National Science Foundation Division of Biological Infrastructure (NSF-REU) and the Department of Defense Awards to Stimulate and Support Undergraduate Research Experiences (DoD-ASSURE) as well as a grant from the University of California Office of the President's UC-Historically Black Colleges and Universities (UC-HBCU) Initiative.

ABBREVIATIONS

CURE: Course-based Undergraduate Research Experience; DoD-ASSURE: Department of Defense Awards to Stimulate Undergraduate Research Experiences; HBCUs: Historically Black Colleges/Universities; NSF-REU: National Science Foundation Research Experiences for Undergraduates Program; RCR: Responsible Conduct of Research; SCCT: Social Cognitive Career Theory; SURE: Survey of Undergraduate Research Experiences; UC-HBCU: University of California - Historically Black Colleges and Universities; URSSA: Undergraduate Research Student Self-Assessment

REFERENCES

Ballen, C. J., Wieman, C., Salehi, S., Searle, J. B., and Zamudio, K. R. (2017). Enhancing diversity in undergraduate science: Self-efficacy drives performance gains with active learning. CBE Life Sciences Education, 16(4). https://doi.org/10.1187/cbe.16-12-0344

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. Psychological Review, 84(2). https://doi.org/10.1037/0033-295X.84.2.191

Berryman, S. E. (1983). Who will do science? trends, and their causes in minority and female representation among holders of advanced degrees in science and mathematics. A special report. A Special Report: The Rockefeller Foundation.

Branchaw, Janet, Butz, Amanda, and Smith, Amber. (2020). Entering Research: A Curriculum to Support Undergraduate and Graduate Research Trainees. W. H. Freeman and Company.

Burgoon, J. M., Meece, J. L., and Granger, N. A. (2012). Self-efficacy's influence on student academic achievement in the medical anatomy curriculum. Anatomical Sciences Education, 5(5), 249–255.

Burke, A., Okrent, A., Hale, K., and Gough, N. (2022). The State of US Science and Engineering 2022. National Science Board Science and Engineering Indicators. NSB-2022-1. National Science Foundation.

Byars-Winston, A., Estrada, Y., Howard, C., Davis, D., and Zalapa, J. (2010). Influence of social cognitive and ethnic variables on academic goals of underrepresented students in science and engineering: A multiple-groups analysis. Journal of Counseling Psychology, 57(2). https://doi.org/10.1037/a0018608

Dall, T. M., Storm, M. V., Chakrabarti, R., Drogan, O., Keran, C. M., Donofrio, P. D., Henderson, V. W., Kaminski, H. J., Stevens, J. C., and Vidic, T. R. (2013). Supply and demand analysis of the current and future US neurology workforce. Neurology, 81(5), 470–478. https://doi.org/10.1212/WNL.0b013e318294b1cf

David, M. E., and Amey, M. J. (2020). National Center for Education Statistics. In The SAGE Encyclopedia of Higher Education. https://doi.org/10.4135/9781529714395.n400

Estrada, M., Burnett, M., Campbell, A. G., Campbell, P. B., Denetclaw, W. F., Gutiérrez, C. G., Hurtado, S., John, G. H., Matsui, J., McGee, R., Okpodu, C. M., Joan Robinson, T., Summers, M. F., Werner-Washburne, M., and Zavala, M. E. (2016). Improving underrepresented minority student persistence in STEM. CBE Life Sciences Education, 15(3). https://doi.org/10.1187/cbe.16-01-0038

Estrada, M., Woodcock, A., Hernandez, P. R., and Schultz, P. W. (2011). Toward a model of social influence that explains minority student integration into the scientific community. Journal of Educational Psychology, 103(1). https://doi.org/10.1037/a0020743

Flores, L. Y., Robitschek, C., Celebi, E., Andersen, C., and Hoang, U. (2010). Social cognitive influences on Mexican Americans' career choices across Holland's themes. Journal of Vocational Behavior, 76(2). https://doi.org/10.1016/j.jvb.2009.11.002

Gainor, K. A., and Lent, R. W. (1998). Social cognitive expectations and racial identity attitudes in predicting the math choice intentions of Black college students. Journal of Counseling Psychology, 45(4). https://doi.org/10.1037/0022-0167.45.4.403

Hernandez, P. R., Woodcock, A., Estrada, M., and Schultz, P. W. (2018). Undergraduate research experiences broaden diversity in the scientific workforce. BioScience, 68(3), 204–211.

Hong, L., and Page, S. E. (2004). Groups of diverse problem solvers can outperform groups of high-ability problem solvers. Proceedings of the National Academy of Sciences of the United States of America, 101(46). https://doi.org/10.1073/pnas.0403723101

Howell, L. P., Wahl, S., Ryan, J., Gandour-Edwards, R., and Green, R. (2019). Educational and career development outcomes among undergraduate summer research interns: A pipeline for pathology, laboratory medicine, and biomedical science. Academic Pathology, 6, 2374289519893105.

Hunter, A.-B., Seymour, E., Laursen, S., Thiry, H., and Melton, G. (2010). Undergraduate research in the sciences: Engaging students in real science. John Wiley and Sons.

Hunter, A.-B., Weston, T. J., Laursen, S. L., and Thiry, H. (2009). URSSA: Evaluating student gains from undergraduate research in the sciences. CUR Quarterly, 29(3), 15–19.

Hussar, B., Zhang, J., Hein, S., Wang, K., Roberts, A., Cui, J., Smith, M., Mann, F. B., Barmer, A., and Dilig, R. (2020). The condition of education 2020. NCES 2020-144. National Center for Education Statistics.

James Gentile, K. B., and Amy Stephens. (2017). Undergraduate Research Experiences for STEM Students. National Academies of Sciences, Engineering and Medicine.

Jin, Y., Qian, C., and Ahmed, S. (2022). Closing the loop: A 10-year Follow-up survey for evaluation of an NSF REU site. 2022 ASEE Annual Conference and Exposition.

Kezar, A. J., and Kinzie, J. (2006). Examining the ways institutions create student engagement: The role of mission. Journal of College Student Development, 47(2), 149–172.

Komarraju, M., and Nadler, D. (2013). Self-efficacy and academic achievement: Why do implicit beliefs, goals, and effort regulation matter? Learning and Individual Differences, 25, 67–72.

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

Lent, R. W., Brown, S. D., and Larkin, K. C. (1984). Relation of self-efficacy expectations to academic achievement and persistence. Journal of Counseling Psychology, 31(3). https://doi.org/10.1037/0022-0167.31.3.356

Lopatto, D. (2004). Survey of undergraduate research experiences (SURE): First findings. Cell Biology Education, 3(4), 270–277.

Lopatto, D. (2007). Undergraduate research experiences support science career decisions and active learning. CBE—Life Sciences Education, 6(4), 297–306.

Nagda, B. A., Gregerman, S. R., Jonides, J., Von Hippel, W., and Lerner, J. S. (1998). Undergraduate student-faculty research partnerships affect studen retention. The Review of Higher Education, 22(1), 55–72.

National Academies of Sciences and Medicine. (2017). Undergraduate research experiences for STEM students: Successes, challenges, and opportunities.

Pajares, F., and Graham, L. (1999). Self-efficacy, motivation constructs, and mathematics performance of entering middle school students. Contemporary Educational Psychology, 24(2). https://doi.org/10.1006/ceps.1998.0991

Pajares, F., and Urdan, T. (2005). Self-efficacy beliefs of adolescents. In Self-Efficacy Beliefs of Adolescents.

Pintrich, P. R., and DeGroot, E. (1990). Quantitative and qualitative perspectives on student motivational beliefs and self-regulated learning. Annual Meeting of the American Educational Research Association, Boston, MA, 128.

Prince, L. Y., Williams, T. B., Allen, A. R., McGehee Jr, R. E., and Thomas, B. R. (2022). Outcomes of the UAMS summer undergraduate research program to increase diversity in research and health professions. Advances in Physiology Education, 41, 20-25.

Riegle-Crumb, C., King, B., and Irizarry, Y. (2019). Does STEM stand out? Examining racial/ethnic gaps in persistence across postsecondary fields. Educational Researcher, 48(3), 133–144.

Russell, S. H., Hancock, M. P., and McCullough, J. (2007). Benefits of undergraduate research experiences. Science, 316(5824), 548–549.

Tsui, L. (2007). Effective strategies to increase diversity in STEM fields: A review of the research literature. The Journal of Negro Education, 555–581.

Weston, T. J., and Laursen, S. L. (2015). The undergraduate research student self-assessment (URSSA): Validation for use in program evaluation. CBE—Life Sciences Education, 14(3), ar33.

Zhai, J., Jocz, J. A., and Tan, A.-L. (2014). 'Am I like a scientist?': Primary children's images of doing science in school. International Journal of Science Education, 36(4), 553–576.