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Sustainable Research Pathways: Collaborations across Communities to Diversify the National Laboratory Workforce

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Dr. Leung is a nationally acclaimed leader in the design and implementation of innovative programs aimed at developing the next generation of science, technology, engineering, and mathematics (STEM) leaders. As an accomplished scientist, Mary Ann honors and treasures the process of scientific discovery. As the director of major STEM-focused educational programs, Dr. Leung nurtured her passion for connecting students and science by developing and implementing novel and measurably impactful initiatives. At Sustainable Horizons, her combined experience base in science and education formulates the presence that is shaping STEM futures.

As program manager for the Department of Energy (DOE) Computational Science Graduate Fellowship (CSGF) program, Dr. Leung evangelized the use of high performance computing by developing workshops, arranging for large allocations coupled with training and mentoring, and increasing usage of DOE supercomputing resources. During her tenure, the program achieved an unprecedented level of recruitment and fellow and alumni engagement, represented by a strategic, multifaceted integration of online, regional, professional society, and annual conference activities. As a result of her efforts, in five years DOE CSGF doubled the number and overall quality of applicants, including a doubling and in some cases quadrupling the number of underrepresented minority applications.

Under her directorship, the National Science Foundation STEM Talent Expansion Program at Miami Dade College witnessed development and implementation of novel programming for cross-engagement of women and under-represented minorities in STEM. She initiated a rapid start, and then engaged and retained students through online and learning communities, specialized courses, virtual and traditional seminars, peer and faculty mentoring, field trips, and other activities.

A computational chemist by training, Dr. Leung is an experienced author and researcher. Her research interests include the development of scalable, parallel, scientific codes for the investigation of quantum mechanical phenomena. Her research is published in several peer-reviewed journals and she remains in-demand as a speaker and contributor at national STEM-based initiatives. She chaired the SC14 Broader Engagement committee, served on the American Association for the Advancement of Science Committee on Opportunities in Science and was an Iowa delegate for Vision 2020, a national gender equity imitative. She also worked with middle and high school girl outreach programs. She graduated with honors from Mills College, earning a B.A. in Chemistry with a Math minor. Dr. Leung holds a Ph.D. and an M.S. in Computational Physical Chemistry from the University of Washington.

Dr. Silvia Crivelli,

Silvia Crivelli is a computational biologist who has been working on protein folding for 20 years. She has led various teams of students and post-doctoral researchers to compete in CASP (Critical Assessment of techniques for protein Structure Prediction) which is a community-wide, worldwide, multidisciplinary competition that challenges the best labs to submit blind predictions of protein structures every other summer. She recently started the WeFold coopetition (collaboration and competition) experiment that brings together research scientists and citizen scientists to solve one of the 100 top outstanding challenges in science. This large-scale open online coopetition is mediated by the homonymous science gateway (http://wefold.nersc.gov). She wants to leverage the unique character of the social-media-based collaborative research community created by WeFold to develop next generation STEM researchers and to help those young researchers further their professional networks and scientific expertise.

Silvia was born in Argentina, graduated in Applied Math at Argentina's National University, and came to the United States to pursue a PhD in Computer Science at the University of Colorado, Boulder. Her interest in applying math and computer science to the solution of scientific problems took her to Berkeley where she completed two post-doctoral research positions, one at NERSC (National Energy Research Scientific Computing) center at Lawrence Berkeley National Laboratory and another in the Bioengineering

Department at University of California Berkeley. During her Berkeley years her interest in science became a passion that she currently shares with the students and postdocs that work with her at the Lawrence Berkeley Lab.

As a member of the selection and steering committees for the Department of Energy (DOE) Computational Science Graduate Fellowship (CSGF) program, Silvia has tirelessly worked on the mission to diversify the list of awardees to include more women and people from underrepresented groups. She believes that progress in science will come from the rich combination of ideas that only a highly diverse community can create and that the current generation has the responsibility to provide the means to open doors to individuals from all walks of society.

Sustainable Research Pathways: Building Connections across Communities to Diversify the National Laboratory Workforce

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Abstract:

The Sustainable Research Pathways (SRP) program is a partnership between the Computing Sciences Division of the Lawrence Berkeley National Laboratory, a Department of Energy National Laboratory, and Sustainable Horizons Institute, a nonprofit organization. SRP aims to create research opportunities for students and faculty from underrepresented, low-income, and first-generation communities that lead to long-term, productive relationships and research collaborations with DOE Laboratory researchers. To initiate and realize the full potential of these relationships the program organizes an annual matching workshop followed by summer internships at the laboratory packed with research and educational activities focused on computational science and high-performance computing. Visiting faculty and students are recruited from a variety of institutions including minority serving, women's, liberal arts, community colleges and other educational institutions. Selected qualified faculty applicants attend a matching workshop in which both, faculty and Laboratory researchers briefly present their work, learn about potential research collaborations, engage in one-on-one discussions, and develop collaborative research proposals. Faculty who are matched to Laboratory researchers engage in an intensive summer research experience at the Laboratory with a few of their students or in some cases send students to engage in a summer Laboratory research experience. Visiting faculty often extend the impact of the program by using their research experience in the classroom at their home institutions, and many of them continue their collaborations at the Laboratory during subsequent summers with a new group of students. We present data on recruitment, the matching workshop, and research experiences, illustrating how the program has successfully created opportunities that changed the professional trajectory of many participants, infused a new dimension of diversity awareness among Laboratory staff, brought people together that would probably never have met otherwise, started new productive collaborations, and provided vibrant research experiences for faculty who otherwise have scarce opportunities for research.

1 Introduction

Computational science and engineering (CSE) was established as one of the pillars of scientific discovery many decades ago and the field has seen much growth since then. The coupling of high end computing with CSE has led to even more growth and the field has become an increasingly important paradigm to advance scientific knowledge and develop the nation's economy. With this growth comes an increasing demand for a highly skilled CSE workforce. A National Council report on competitiveness identifies high-end computing as playing a "vital role in driving private-sector competitiveness" (1). The U.S. Department of Energy (DOE) has played a pivotal role in the development and use of CSE and high end computing and maintains a leadership position. However, it has been noted by the DOE Advanced Scientific Computing Advisory Committee (2) and others (3) (4) (5) that the DOE Laboratories face workforce development and recruitment challenges. Further complicating the matter is the underrepresentation of women and minorities in high end computing. Disparities in representation and participation impede educational attainment and access to the Science and Technology (S&T) workforce. While underrepresentation and lack of diversity are noted generally across S&T fields, they are more

pronounced in mathematical and computing sciences (6) (7) (8) (9). Statistically, women earn approximately 40 percent of the undergraduate degrees in mathematics; however, underrepresentation of African Americans and Hispanics in mathematics persists (10) (11). Gender variation has been marked in computing baccalaureate and doctorate attainment and employment with minorities showing even greater disparities (12).

Recognizing the workforce and diversity needs and the importance of apprenticeship internship experiences (13), Lawrence Berkeley National Laboratory (LBNL) Computing Sciences and Sustainable Horizons Institute (SHI) partnered in a project aimed at building sustainable pathways that promote research partnerships leading to an increase in the breadth and quality of the Computing Sciences workforce. LBNL recognizes the need to nurture a strong and diverse workforce and foster inclusionary and inter- and multi-disciplinary scientific research. The Sustainable Research Pathways (SRP) project works in tandem with and supplements on-going laboratory activities to diversify the LBNL scientific staff.

Current activities at LBNL include efforts aimed at increasing the diversity of the applicant pool for opportunities within the Computing Science division. SRP is aimed at providing opportunities and developing on-going relationships with faculty and students from diverse backgrounds through research collaborations. Exposure to the rich scientific community and culture at LBNL may significantly impact the trajectories of faculty and student participants. SRP is comprised of faculty recruitment, matching workshop, and summer research experience.

While the program is still fairly young and thus the numbers relatively small, case study data are presented herein covering program recruitment, matching workshop, and research experiences from 2015 through 2017. Discussion of the data is presented followed by concluding remarks.

2 Data Collection

Applicant and participant data were collected using an online submission system. In 2015 through 2017, 230 applications were received from faculty who proposed to include 350 students. Sixty-five faculty representing 144 students attended the matching workshops and 27 faculty and 61 students participated in summer research experiences. Recruitment and participation data presented below in Sections 3, 4, and 5 were compiled from the submission data.

To measure program impacts a survey was administered in 2017 to the students and faculty that participated in SRP summer research in 2016 and 2017, and all staff who participated in the application reviews, matching workshop, and/or summer research projects.

Surveys were sent to the 33 students who participated in summer research in 2016 and 2017 and 9 students, 27 percent, responded to the survey. Eighteen faculty participated in the SRP summer research in 2016 and 2017. Ten of the 18 responded to the impact survey. Eighty-seven laboratory staff who served as reviewers, attended the workshop, and/or hosted teams were asked to complete an anonymous survey about their experience with the SRP program. Twenty responses were received. Survey results are summarized below in Section 6. Given the relatively small number of responses to the survey in some cases, we present the results in case study format.

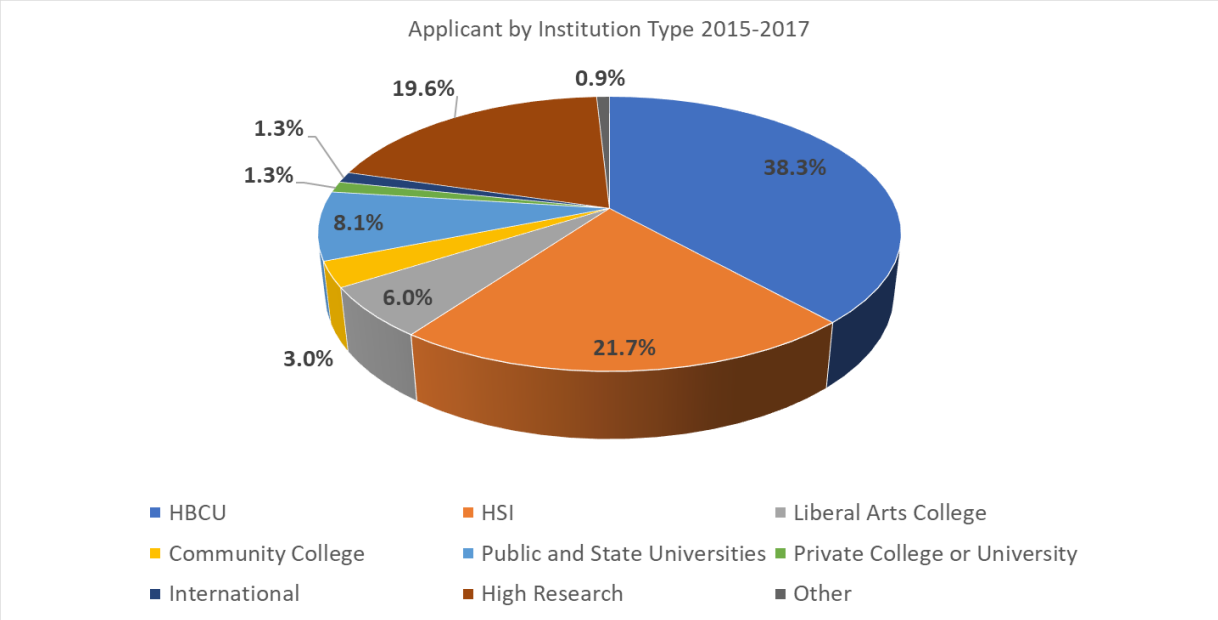
3 Recruitment

Faculty and students were recruited, according to interest and achievement from a variety of academic institutions. Recruitment efforts especially focused on Minority Serving Institutions (including, among others, Historically Black Colleges and Universities, Hispanic Serving Institutions); women's, community, and liberal arts colleges; diversity focused professional conferences (e.g., Grace Hopper Celebration of Women in Computing and Tapia Celebration of Diversity in Computing); and diversity focused fellowship programs. A variety of electronic media, an extensive professional network, and in-person visits were utilized for recruitment. These activities yielded a total of 89, 68, and 73 applicants in 2015, 2016, and 2017.

Applicants

Applications were received from a variety of institutions, as shown in the data below. Sixty percent of the applicants came from Minority Serving Institutions comprised of 38.3 percent Historically Black Colleges and Universities (HBCU) and 21.7 percent Hispanic Serving Institutions (HSI). High research institutions made up 19.6 percent with the other applicants at liberal arts colleges, community colleges, public and state universities, private colleges and universities, as shown in Figure 1.

Figure 1 Applicant Institutions by Type



4 Selection and Invitation to Matching Workshop

Applications were reviewed by Laboratory staff for technical merit and potential for collaboration. Applicant and student demographic data was not shared with technical reviewers.

Laboratory staff reviewed applications based on the applicant's stated research interests, experience, and their interest in potential mentors. Some applications were reviewed by multiple staff members where there appeared to be multiple potential matches. Applications were reviewed and scored based on following factors:

- confidence/interest in the applicant's research
- potential for collaboration
- support for invitation to workshop
- availability to work with the team

All review data including quantitative scores and reviewer comments were compiled and selections were made based on potential for successful matches.

At the end of the workshop, faculty provided a list of the staff/research project(s) they were interested in pursuing. The following day, a debriefing meeting was held with staff to determine which faculty teams they were interested in working with. Matches then moved forward with applications for funding the summer experience. Fourteen, 22, and 17 faculty were matched with staff in 2015, 2016, and 2017 leaving only one, four, and five faculty members not successfully matched with research projects. The match ratios are 90, 80, and 77 percent for the three years respectively, as shown in Table 1. In 2016, Lawrence Livermore National Laboratory and Sandia National Laboratory participated in the workshop and matched with faculty teams, however did not fund any teams for summer research, contributing to the larger number of unfunded teams in 2016.

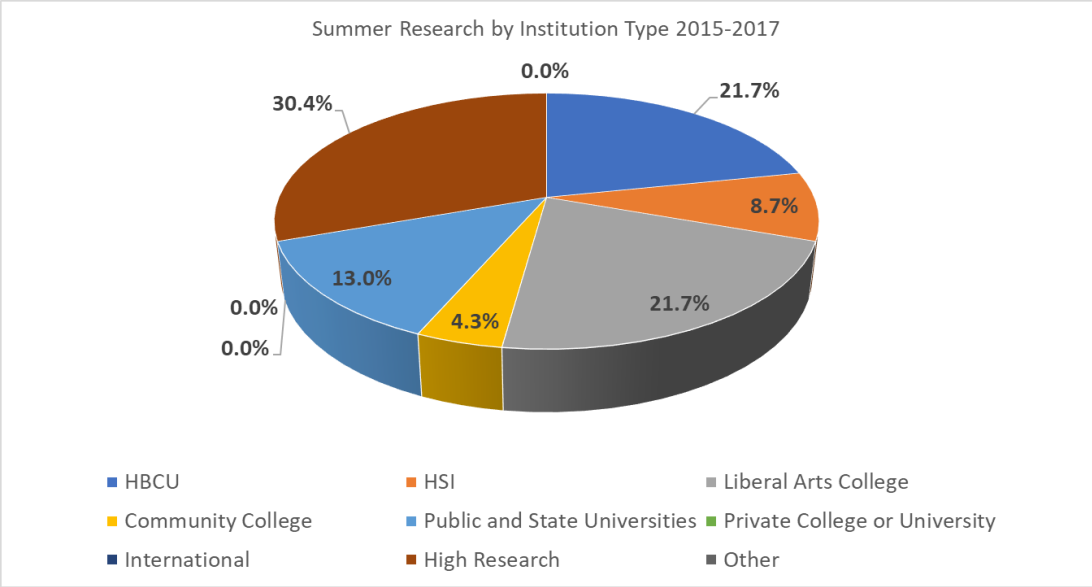
Table 1 Workshop Attendees, Matches, and Summer Research Participants

Year	Number of Faculty Workshop Attendees	Number of Matches	Percentage of Matches	Number Participating in Summer Research	Number Unfunded teams
2015	15	14	90.00%	9	5
2016	26	22	80.00%	9	23
2017	22	17	77.27%	9	8

5 Summer Research Experience

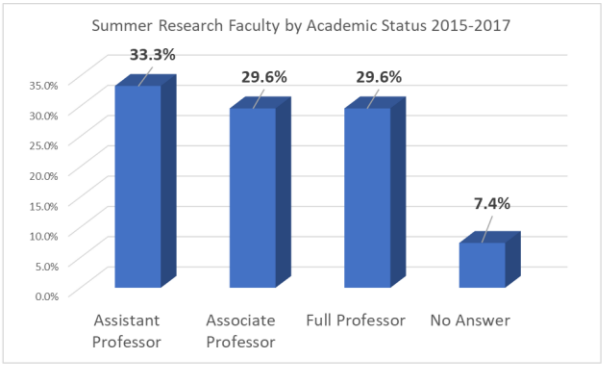
Data on the faculty and their students who received funding for a summer research experience are presented below. Summer research participant institutions for the period of 2015 through 2017 were made up of approximately one third from Minority Serving Institutions (21.7 percent HBCU, 8.7 percent HSI), one third high research, and the rest mainly composed by Liberal Arts Colleges and Public and State Universities, as shown in Figure 2.

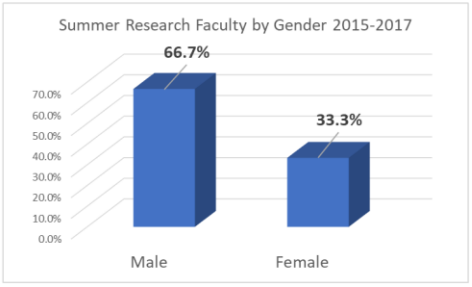
Figure 2 Summer Research Participant Institutions by Type

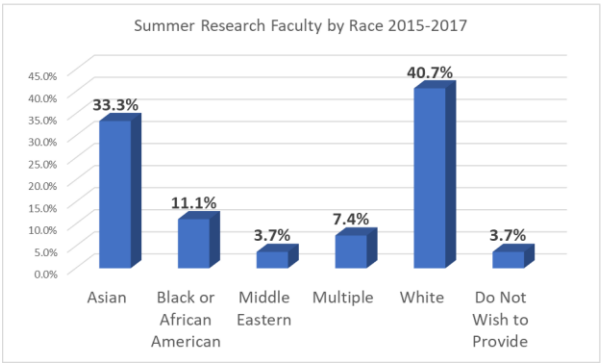


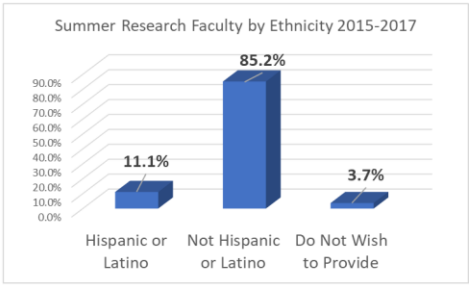
Faculty demographic data is presented in Figure 3. The faculty who participated in summer research from 2015 through 2017 were approximately evenly spread between Assistant, Associate, and Full Professors. One third of the faculty were female, 11 percent were Black or African American, 11 percent were Hispanic or Latino(a), approximately 40 percent White and one third Asians. While the faculty are predominantly Asian and White males, the diversity in the students is far greater as described below.

Figure 3 Summer Research Faculty Demographic Data



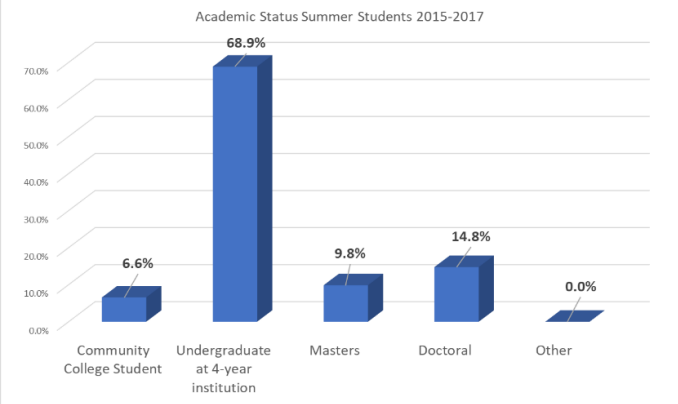


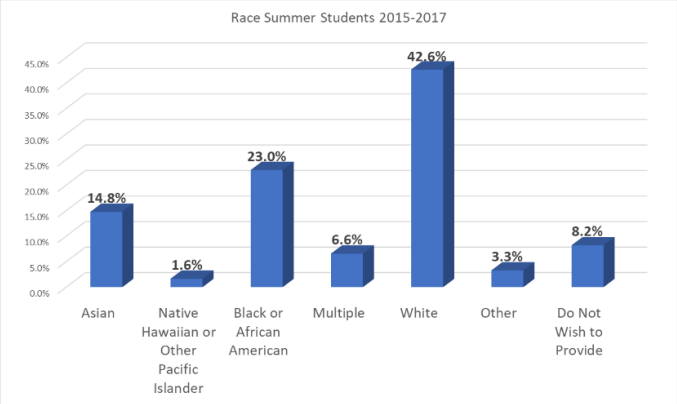


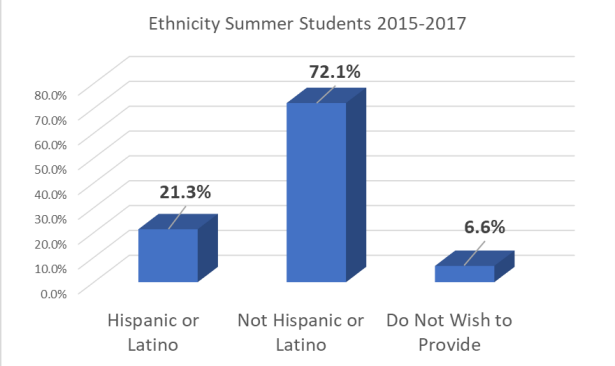


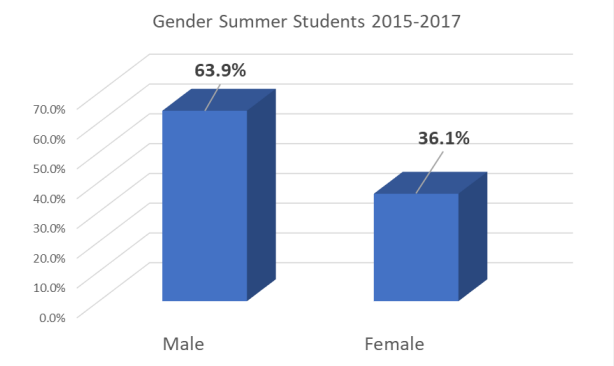
Student demographic data are presented in Figure 4. Nearly 70 percent of the students who participated in the summer research were undergraduates at four-year institutions. Twenty-three percent of the students are Black or African American and 21 percent are Hispanic or Latino, 36 percent female, 3 percent report a disability, and nearly 40 percent are first generation scholars.

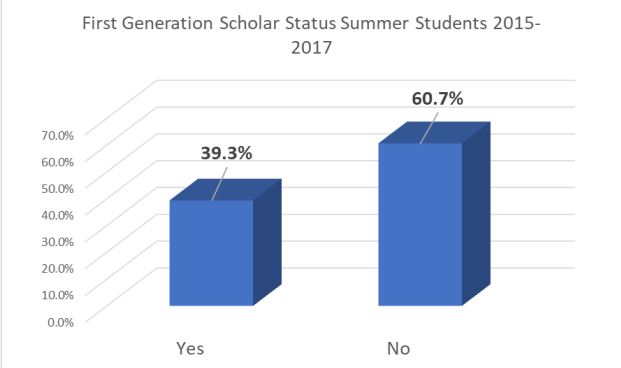
Figure 4 Summer Research Students Demographic Data

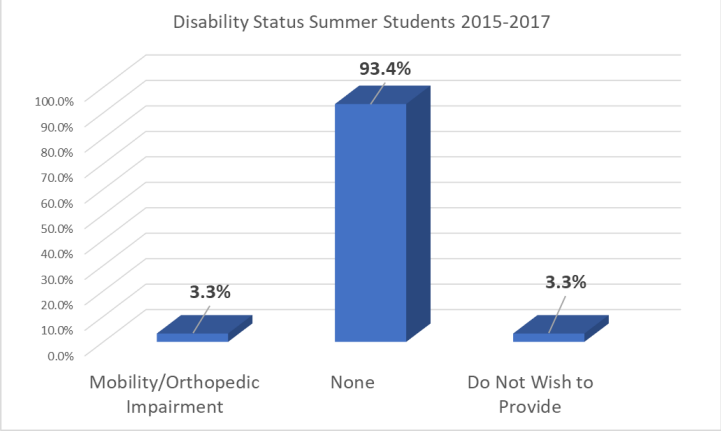












6 Program Impacts

Survey data from students and faculty who participated in summer research experiences and all laboratory staff who reviewed applications and/or participated in the matching workshop or summer experience are presented below.

Student Impacts

Student expectations and impacts are shown in Figure 5. Seventy-five percent of student respondents indicate the summer research experience was as expected, impacted their career plans, and impacted their ability to further their educational goals. Over sixty percent presented their research results. Students self image and employment plans are presented in Figure 6. Half of the students indicated that the experience changed how they envisioned themselves as scientists. Seventy-five percent indicated plans to seek employment in industry prior to the summer experience, while only twenty-five percent remained with those plans after the summer experience. Responses moved to going to graduate school, other plans, and unsure. Figure 7 shows fifty percent of respondents indicated a 5 out of 5 overall rating of the experience with nearly 40 percent of respondents indicating a 4 out of 5 with 5 being the best score. Respondents ranked educational or career opportunities as the most important benefit of participating in the program followed by inspiration.

Figure 5 Student Expectations and Impacts

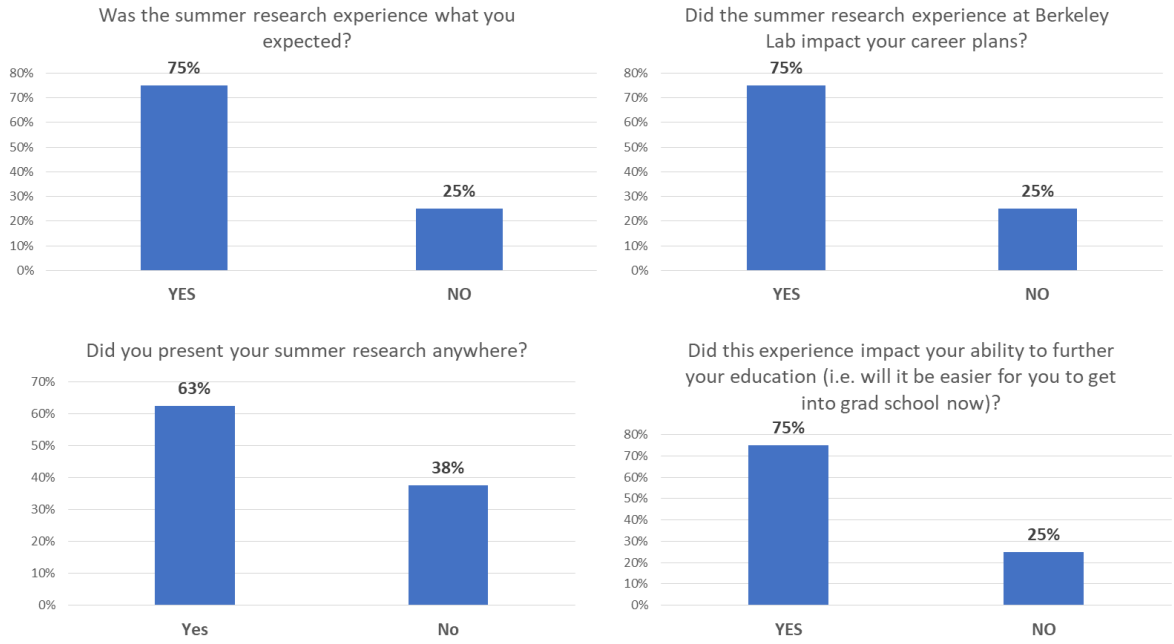
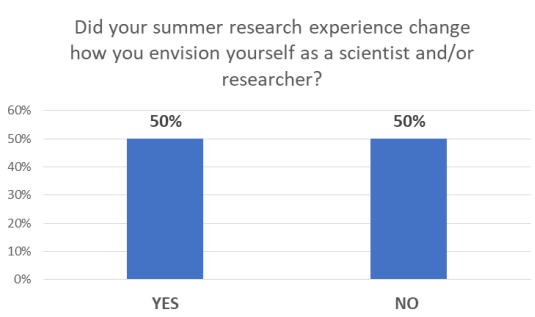


Figure 6 Student Self Image and Employment Plans



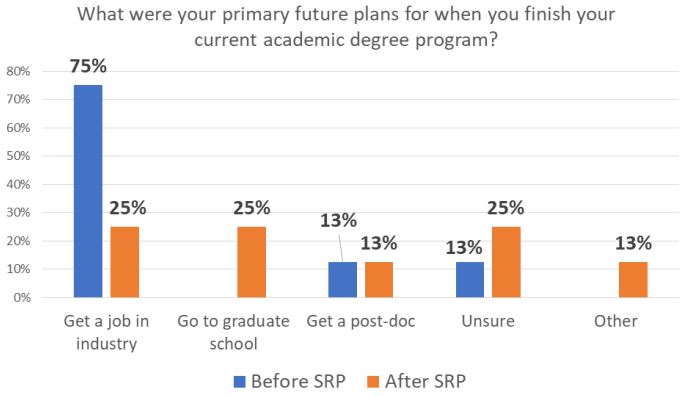
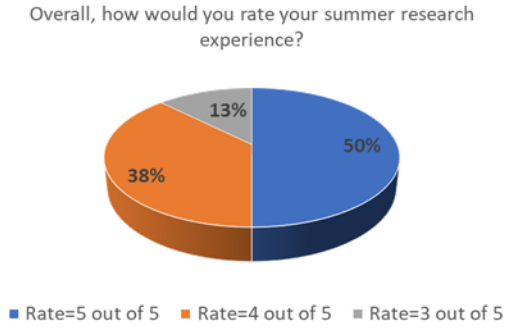
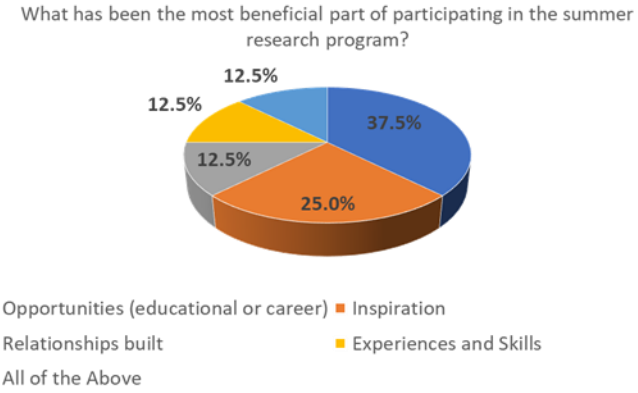


Figure 7 Student Overall and Benefit Impressions





While 75 percent of respondents indicated that their expectations were met, an analysis of student comments indicate in some cases the research experience far exceeded their expectations. Other comments indicated the experience had dramatically changed their trajectory, influenced them to pursue graduate school, impacted their image of themselves as scientists and helped them define what they want for their future career.

Faculty Impacts

Faculty were asked to rate the SRP workshop and summer experience components from 1 to 5 with 5 being the best score, with the following results shown in Figure 8.

- Average scores range from the 4.3 to 4.8 out of 5 with the staff presentations, welcome dinner, and preparations receiving the highest average score of 4.8
- Average rating of knowledge of DOE laboratories increased from 3.1 before the workshop to 4.2 out of 5 after the workshop.

Figure 8 Faculty Ratings of SRP Components

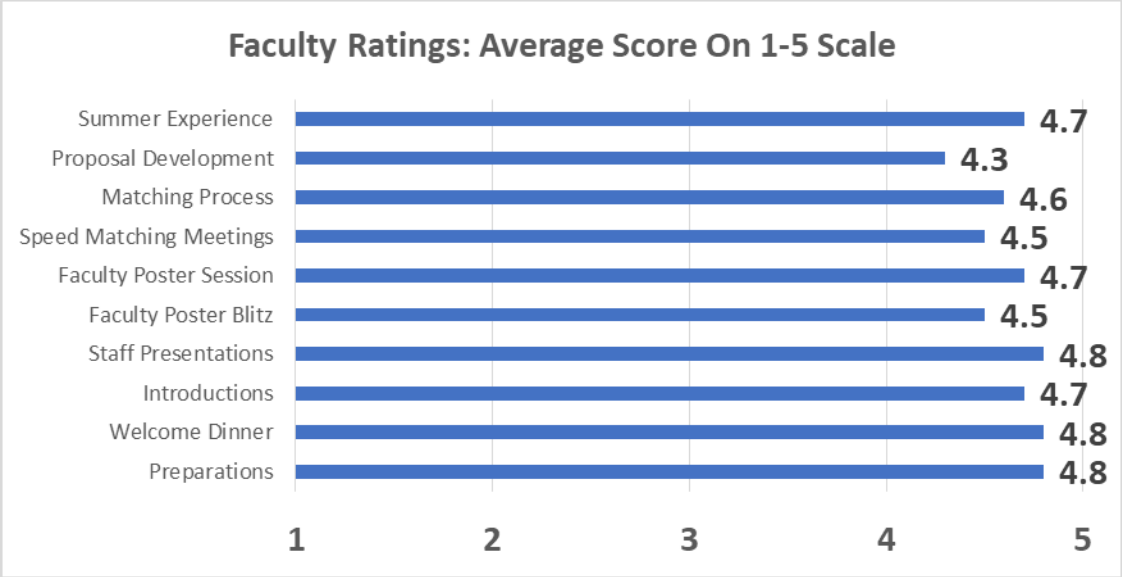


Figure 9 shows faculty understanding of the DOE labs increased from 3.1 before the workshop to 4.2 afterwards. Over eighty percent of faculty indicated that their expectations for the summer experience were met and over seventy percent indicated that the experience impacted their professional life. Seventy percent indicated that the experience also impacted their teaching and over sixty percent indicate they are continuing their collaborations with Laboratory staff, as shown in Figure 10.

Figure 9 Faculty Ratings of Their Understanding of DOE Labs before and after Workshop

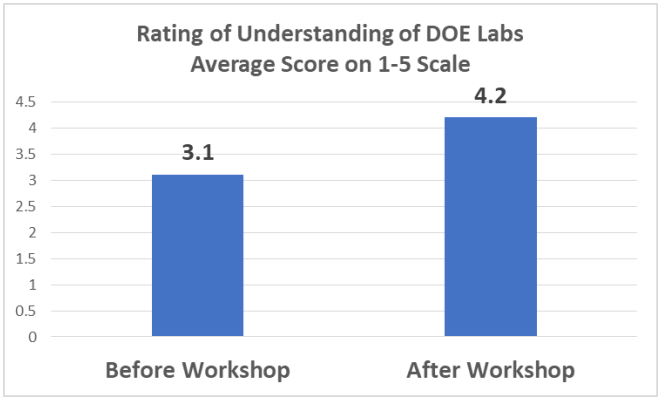
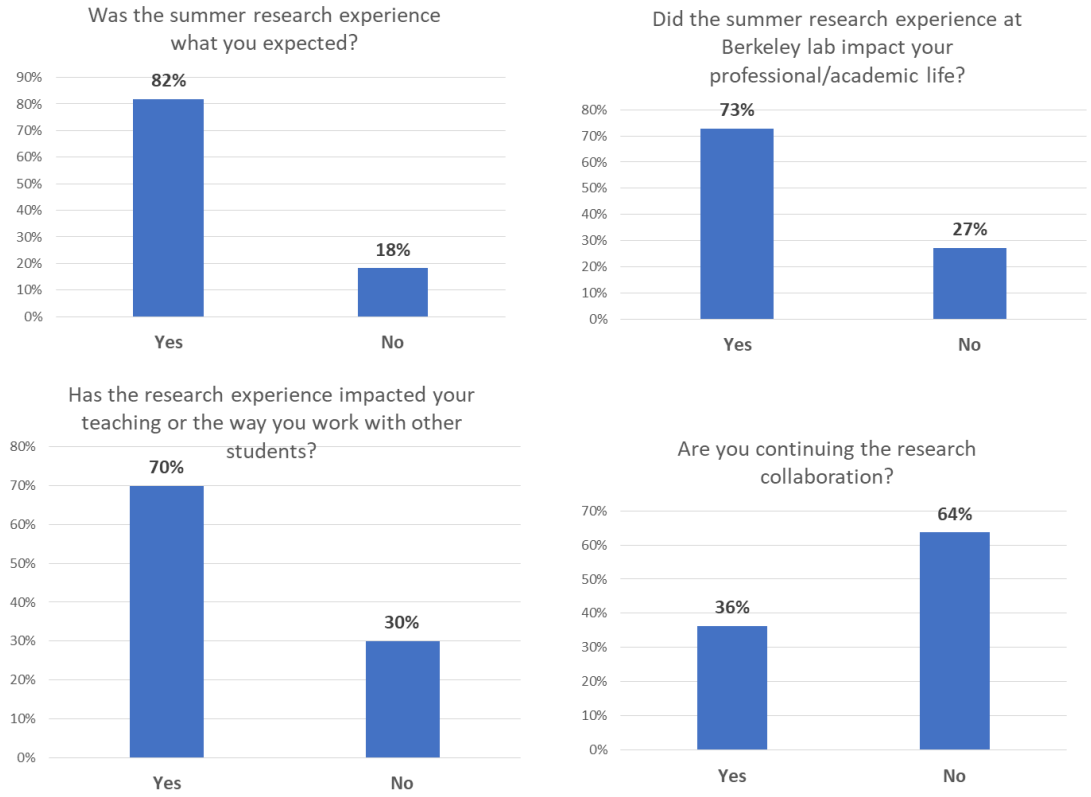


Figure 10 Faculty Summer Research Impacts



Research productivity was reported as the production of peer reviewed papers, conference papers, and conference presentations, with three faculty reporting one peer reviewed paper and one faculty reporting three peer reviewed papers, two faculty reported one conference paper, three faculty reported one conference presentation, two faculty reported two presentations, and two faculty reported three conference presentations, as show in Table 2.

Table 2. SRP Faculty Research Output

Type of Research Output	Number of Research Output Reported	Number of Faculty Reporting
Peer Reviewed Paper	1	3
Peer Reviewed Paper	3	1
Conference Papers	1	2
Conference Presentations	1	3
Conference Presentations	2	2
Conference Presentations	3	2

An analysis of survey comments indicate that several faculty found that the experience exceeded their expectations, the experience was well organized and productive, lasting relationships were formed, and

there were opportunities to learn about new potential collaboration. One faculty reported an expectation to work on a different research topic and another faculty member expected more collaboration after the summer.

Direct impacts to faculty include:

- increased research and technical skills,
- exposure to new research, collaboration, and funding opportunities,
- new collaborative grant writing opportunities,
- new outreach ideas,
- assistance for students applying to graduate school, and
- experience anticipated to help with academic promotion.

Direct impacts to students reported by faculty include:

- student employment,
- student persistence in research activities,
- access to high performance computing knowledge and scientific software,
- student exposure to the rich DOE research environment, and
- assistance from laboratory mentors in research design.

Faculty report the following impacts to their teaching or interactions with students:

- increased ability and credibility to encourage students to apply for internships,
- increased confidence in conducting research with students,
- increased experience managing undergraduate students in high-impact intensive research projects, and
- experience demonstrating national laboratory capabilities.

The most useful aspects described by faculty are exposure to a wide variety of departments and staff and their expertise, collaboration, and the welcome dinner meeting. Suggestions from faculty include identifying additional groups for collaborations and earlier notification to facilitate student decisions.

Staff Impacts

When asked to rate the SRP components, staff gave the faculty poster blitz the highest average score of 4.2 out of 5 with 5 being the best score, followed by the research experience at 4.1. The matching process, speed matching meetings, faculty poster presentations, staff presentations, and introductions, received slightly lower ratings of 3.9 or 3.8, as shown in Figure 11.

Figure 11 Staff Ratings of SRP Components

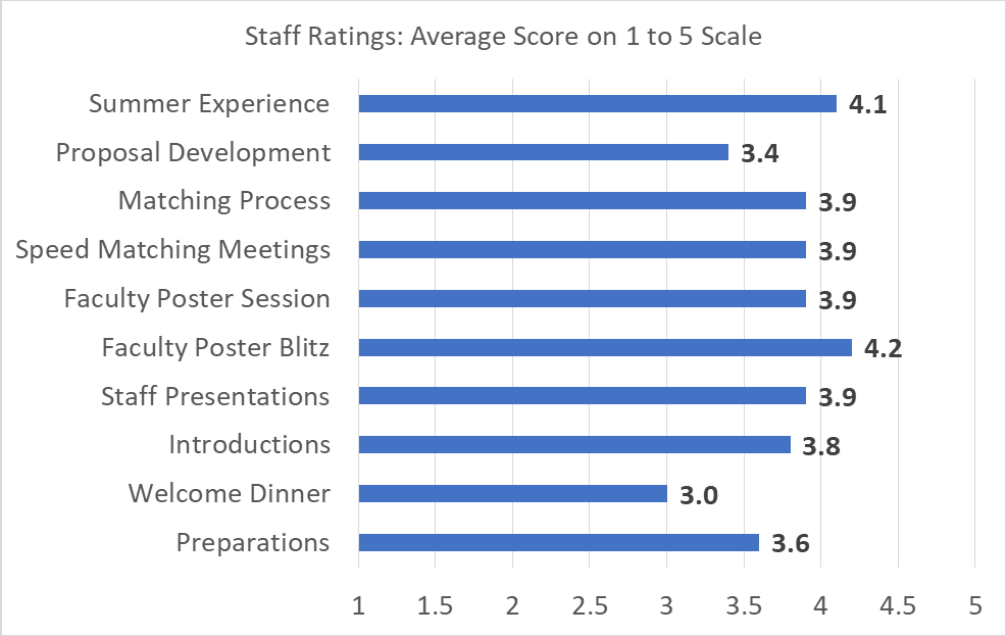


Figure 12 shows forty-five percent of the staff rated research collaboration as what interested them in participating, 20 percent ranked interest in working with students, 20 percent ranked interest/desire to support diversity while organizational goals and all of the above received 5 percent each.

Figure 12 Staff Participation Motivation

Figure 13 indicates thirty-seven percent of the staff respondents hosted faculty and/or students for a research experience.

Figure 13 Staff Participation in Summer Research

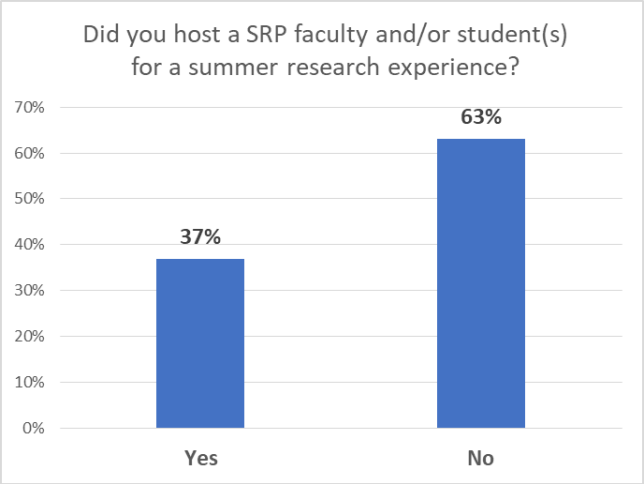
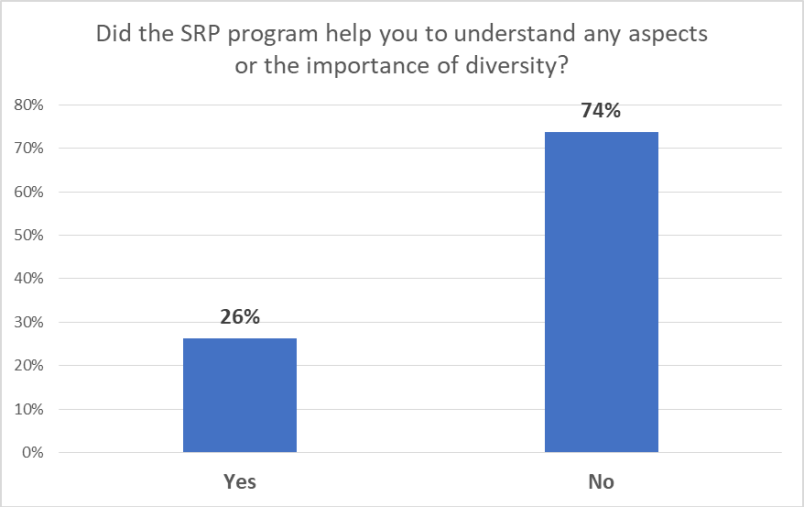


Figure 14 shows twenty-six percent of staff indicated SRP helped them understand aspects or the importance of diversity. Several commented that they already knew about the importance and others indicated that that they are becoming aware of the importance of these students envisioning themselves in contexts such as the lab, and developing an appreciation for these types of events to catalyze new perspectives. Survey comments indicate staff learned the following from SRP faculty or students:

- There is a strong desire to work with the labs
- Department of Energy Laboratories have a lot to offer this population
- Potential talent pool is large
- Breadth of research topics
- New research domains
- Passion for growing research portfolios
- Impressive drive and focus
- Faculty are conducing good research
- Department of Energy Laboratories can benefit from collaborations
- Interesting research exists at smaller institutions

Figure 14 Impact on Staff: Knowledge about Diversity and Inclusion

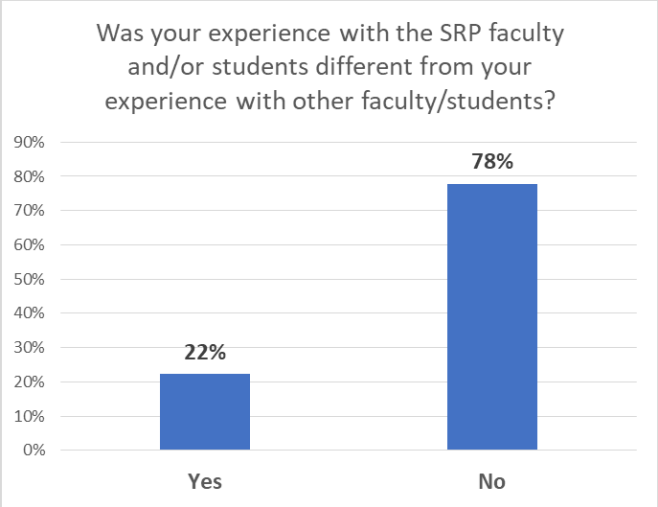


Staff reported the following benefits from their SRP experience:

- Joint proposal submission
- Broadening research directions
- Reviewing proposals
- Watching good relationships develop at the laboratory
- New connections

Nearly 80 percent of the staff reported no difference between their experience working with SRP faculty and/or students and other faculty and students, as shown in Figure 15. Staff comments indicated that sometimes faculty are less capable at supervising students in research requiring staff to work more directly with the students than expected, which was viewed positively. Other staff commented that they were able to work on a new problem and were motivated to explore it in more detail and the students appeared very aware of the special nature of their experience at the Laboratory. Some commented that they normally work with teams that have closer research interests to their own and a different level of engagement.

Figure 15 Comparison of Staff Experience with Students and Faculty



An analysis of textual responses indicate that the most important aspects of the workshop include: learning about institutions that they would not otherwise be exposed to, engaging one-on-one with faculty during the poster session and/or one-on-one meetings, and meeting new people interested in high performance computing.

Staff made the following suggestions:

- Funding opportunities for the summer need to be explained to faculty and staff more clearly
- Some felt the current review process needed improvement, while others thought it was sufficient
- Provide more guidance to participants at each part of the process
- Process is evolving well

7 Discussion

An analysis of the recruitment and summer experience data and survey results is presented below.

Analysis of Recruitment and Summer Experience Data

Recruitment has yielded significant interest from Historically Black Colleges and Universities, Hispanic Serving Institutions, and high research institutions. There also is interest from faculty at liberal arts and community colleges and public and state universities. Minority Serving Institutions, comprised of Historically Black Colleges and Universities and Hispanic Serving Institutions, represent the largest portion of the applicant pool and while their portion of the summer research participants is smaller their combined summer participation is approximately one third. Liberal arts colleges gain significant proportions from 6.0 percent of the applicant pool to 21.7 percent of the summer participating institutions while high research institutions gain approximately 11 percent points, as shown in Table 3. These data suggest an examination of factors contributing to the number of research participants from Minority Serving Institutions.

Table 3 Institutional Type by Average Percentage for Applicant and Summer Research Participants

Institution Type	Applicant (Average %)	Summer (Average %)	Change (Summer- Applicant) %
HBCU	38.3	21.7	-16.6
HSI	21.7	8.7	-13.0
Liberal Arts College	6.0	21.7	15.8
Community College	3.0	4.3	1.4
Public and State Universities	8.1	13.0	5.0
Private College or University	1.3	0.0	-1.3
International	1.3	0.0	-1.3
High Research	19.6	30.4	10.9
Other	0.9	0.0	-0.9

A comparison of the faculty and student demographics for applicants and summer research participants indicates consistency of representation in most areas, as shown in Table 4. Black or African American faculty and students showed lower representation in the summer experience by 4.5 and 7.9 percent, representing 37.5 and 34.3 percent decline respectively. There is a consistently high representation of Asian faculty leading to a relative small percentage of Caucasian faculty averaging 40 percent. And while the Asian student population is much smaller than the Asian faculty the Caucasian representation among the student remains at approximately 40 percent. The larger representation of diversity in the student population is viewed favorably as the ultimate goals are to impact student trajectories. Nonetheless, we note that an examination of factors leading to the loss of diversity in the faculty is needed. Additional targeted recruitment at minority serving institutions where successful summer research experiences have been demonstrated is under discussion.

The academic status of students of applicants and summer research teams consists largely of undergraduates at four-year institutions including nearly 70 percent of summer students. Community college student representation increased significantly between the applicant pool and the summer research participants. Working with a large percentage of undergraduate students provides ample opportunity for impact on student academic and career trajectories.

Table 4 Comparison of Average Demographics for Faculty and Student Applicants and Summer Research Participants

Demographic		Applicants (Average %)	Summer Participants (Average %)	Change: Summer-Applicant (Average %)	Percent Change
Faculty	Female	27.8	32.0	4.2	13.1
	Black or African American	16.5	12.0	-4.5	-37.5
	Hispanic or Latino	12.0	12.0	0.0	0.0
	Asian or Pacific Islander	39.6	32.0	-7.6	-23.8
	Caucasian	30.8	40.0	9.2	23.0
	Multiple Races	7.0	8.0	1.0	12.5
Students	Female	36.0	36.1	0.1	0.3
	Black or African American	30.9	23.0	-7.9	-34.3
	Hispanic or Latino	21.4	21.3	-0.1	-0.5
	Asian or Pacific Islander	17.4	14.8	-2.6	-17.6
	Caucasian	31.4	42.6	11.2	26.3
	Multiple Races	4.9	6.6	1.7	25.8
	First Generation Scholar	49.4	39.3	-10.1	-25.7

Table 5 Comparison of Average Student Academic Status of Applicants and Summer Research Participants

Academic Status	Applicant	Summer Research	Change (Summer-Applicant)
Community College Student	3.4	6.5	3.1
Undergraduate at 4-Year Institution	62.9	68.9	6.0
Masters	14.4	9.8	-4.6
Doctoral	19	14.8	-4.2
Other	0.3	0	-0.3

Analysis of Survey Data

Student survey data demonstrate many positive impacts including changing student self-perception, self-efficacy, and career and educational plans. Faculty survey data indicate positive outcome ranging from improved ability to supervise and advise students in research, improved teaching skills and credibility, and new research opportunities.

Staff survey results indicate interest in working with the faculty and students from diverse backgrounds and no presence of bias. Staff indicate a variety of benefits from expanding their own research

portfolios to learning about the ability of faculty and students at smaller colleges to bring new ideas to the table and make important contributions.

Through SRP we have demonstrated an important technique for diversifying the engagement of faculty and students at the Laboratory. Typical recruitment often reaches out to one's own professional network, yielding relatively homogeneous populations. Through SRP we have exposed staff scientists to a new and diverse group of faculty and students that they would have probably never knew existed, been exposed to, nor considered as potential collaborators. Given the research output measured in papers and conference presentations, it has also been demonstrated that diversity does not result in a trade off in quality. We attribute these results to the openness of staff as well as the strong support from the Laboratory division leadership. It is worth noting that we have explicitly included high research institutions, which some diversity focused programs have excluded. Faculty and students from diverse backgrounds at high research institutions play an important role in SRP.

8 Conclusions

Data illustrate how the Sustainable Research Pathways program has successfully created opportunities that changed the professional trajectory of many participants, infused a new dimension of diversity awareness among Laboratory staff, brought people together that would probably never have met otherwise, started new productive collaborations, and provided vibrant research experiences for faculty who otherwise have scarce opportunities for research. There are indications that SRP has significant impact on student trajectories given the shift in their stated career intentions before and after the experience. Comments from students indicate in some cases they felt a dramatic impact characterized as "life changing" along with an increased interest in working at a national laboratory, improved self-efficacy, more clarity in their aspirations, and interest in research rather than technical or programmer positons.

SRP impacts to the faculty range from improved research and technical skills, exposure to new research, collaboration, and funding opportunities, new collaborative grant writing opportunities, new outreach ideas, access to high performance computing knowledge and scientific software, assistance from laboratory mentors in research design, and experience anticipated to help with academic promotion. Faculty cited several benefits to their students and report the impacts to their teaching or interactions with students such as increased ability and credibility to encourage students to apply for internships, confidence in conducting research with students, experience managing undergraduate students in high-impact intensive research projects, and experience demonstrating national laboratory capabilities.

Feedback from the Laboratory staff are generally positive. Staff recognized a large pool of talent and a strong desire from the participants to work with the Laboratory, impressive drive and focus, and a realization that there is interesting research conducted at smaller institutions. Staff acknowledge the benefit of joint proposal submission, opportunity to broaden research directions, and watching good relationships develop. Nearly all staff reported no difference between working with the SRP faculty and students and working with other faculty and students. Staff suggestions include improving the communication and streamlining the funding process.

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