

Lida A. Beninson
 University of Colorado at Boulder
 Jessica Koski
 Yale University
 Erika Villa
 University of Texas El Paso
 Ronnie Faram
 University of Oklahoma College of Dentistry
 Sally E. O'Connor
 National Science Foundation

Evaluation of the Research Experiences for Undergraduates (REU) Sites Program

Introduction

The Research Experiences for Undergraduates (REU) Program, sponsored by the National Science Foundation (NSF), supports the meaningful participation by undergraduate students in most areas of research in science and engineering. NSF provides funding for both stand-alone programs (known as REU Sites) and for individual students conducting research under an NSF-funded project (known as REU supplements). The REU program is a major component of NSF's effort to broaden the participation of individuals, especially those from under-represented groups, in science and engineering research. In order to gain insights for designing REU Sites and to determine the extent to which these programs contribute to the diversity goals of NSF, we gathered information during the summers from 2006 through 2009 on REU Sites funded or co-funded by the NSF's Directorate for Biological Sciences. We believe the findings reported here represent the first comprehensive program-wide evaluation of an REU Sites program.

NSF established the REU Sites Program in 1987, in an effort to increase students' interest in science and to promote the participation of diverse groups in research careers. In Fiscal 2010, NSF used an estimated over \$80 million of its budget to support the REU program (NSF

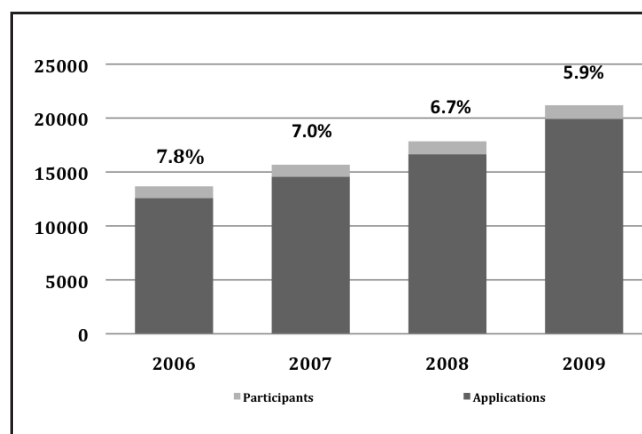
Solicitation 09-598). Undergraduate students' active participation in research is one of the most effective methods of attracting and retaining them in the sciences, and several studies have shown student benefits from an REU-type experience (Lopatto 2007; Russell, Hancock, and McCullough 2007; Seymour et al. 2004; Villarejo et al. 2008). The Directorate for Biological Sciences (BIO) funds several REU Sites programs that provide innovative and exciting research experiences for undergraduates in many areas of the biological sciences. For purposes of this article, all subsequent references to the REU program specifically refer to sites funded or co-funded by BIO.

Survey Methods

Each summer from 2006 through 2009, a survey was sent electronically to the principal investigators (PIs) conducting an REU Sites program. Their responses were collected, and the data compiled and analyzed. Data could have been gathered from annual progress reports submitted by PIs, but this process is tedious and prone to data entry errors. Therefore, collecting data in Excel format from PIs was the route taken. The survey was designed to identify the participant groups' racial and ethnic profiles, academic status, gender, fields of interest, and disability status. Included in the 2008 and 2009 surveys were questions designed to evaluate enrichment activities, recruitment methods, and measures of program success at each site. The response rate from PIs was close to 100 percent for each of the four years of the survey.

For purposes of the REU program, underrepresented minorities are defined as those who self-identify as African Americans, Hispanics, Native Americans (including Alaska Natives and Pacific Islanders), and persons with disabilities. Our survey also tracks Asian, white, and female participants. Students must be U.S. citizens, U.S. nationals, or permanent residents, and be enrolled in an undergraduate degree program to be eligible to participate in the program. It is important to note that data

Figure 1. Total number of REU Sites' applications and participants from 2006 through 2009. Light grey bars show the number of participants, while the combination of light and dark grey bars represents the total number of applications. The percentages above the bars represent the acceptance rate.



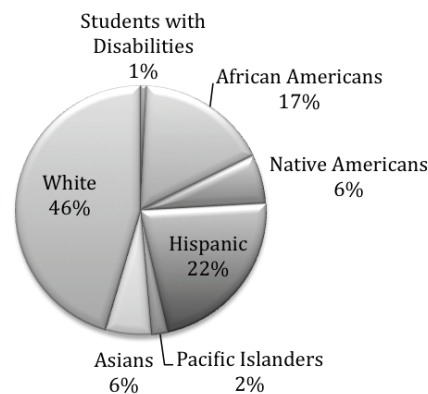
were collected from the REU program directors or PIs, and not from the student participants.

Results and Discussion

Number of Applications and Acceptance Rate The summer 2006 data provided the first glimpse of the overwhelming demand for this program, when PIs collectively received 13,671 student applications for the 106 sites that conducted a program. In the subsequent three summers, the number of sites increased slightly but not in proportion to the number of applications (Figure 1). In 2009, the large number of applications (21,193) resulted in the lowest acceptance rate ever (defined as the ratio of the total number of students who participated to the total number of applications received). The 12 percent drop in the acceptance rate in 2009 was three times higher than the previous year's drop (4 percent). These data clearly show that the number of available opportunities for undergraduates interested in an REU has not kept up with the demand. Because the survey does not provide data on how many applications, on average, a student sends to the sites, it is therefore not possible to infer the extent to which the average number of applications sent by individual applicants influences the acceptance rate.

Demographic Characteristics of Student Participants From 2006 through 2009, the percentage of participants belonging to an underrepresented group has increased (Table 1), from 43 percent in 2006 to 49 percent in 2009. Figure 2 shows the racial and ethnic distribution for summer 2009 participants, indicating participation by undergraduates from all underrepresented groups. The distribution for the other three summers was similar, with some observable trends. While the proportions of Native Americans, Pacific Islanders, and persons with disabilities have remained constant over the four years, the proportion of Hispanic students has steadily risen and that of African Americans has fluctuated slightly during the same study period. These data are consistent with the growing numbers of Hispanic students matriculating in college (The Pew Hispanic Center 2010), and are consistent with advancing NSF's goal of increasing the participation of underrepresented groups in research (National Science Board 2010).

Figure 2. Racial and ethnic distribution of the summer 2009 REU participants



The gender distribution has remained relatively constant over the four years, with a predominance of females (between 62 and 64 percent of participants over the four years). The percentage of non-traditional students, defined as 30 years or older, however, has remained low at 2 to 4 percent. These findings indicate that, overall, the REU program has been successful in recruiting a diverse group of students, including a large number of underrepresented students, and that the various efforts of PIs to reach these populations have been effective.

Academic Background of Student Participants Students who have just completed their freshman year participate in low numbers – an average of 10 percent of the Sites' participants from 2006-2009, although the number increased over the four years (from 9 percent in 2006 to 11 percent in 2009). The largest group of participants was students who had just completed their junior year (57 percent), with the percentage decreasing over the years (58 percent in 2006 compared to 53 percent in 2009). The data indicate that the majority of participants were either rising juniors or seniors. Several REU programs require students to have completed specific science courses, and these data reflect the growing participation of more-advanced students who have completed prerequisite courses.

In 2008 and 2009, PIs were asked to indicate the number of participants from PhD-granting institutions, and our data showed that the majority of students are recruited from non-PhD institutions (61 percent in 2008 and 57 percent in 2009). This result is consistent with the goal of the program to provide opportunities to students whose access to research is limited. In addition, the percentage

of students recruited from outside the host institution has remained consistently high (between 82 and 85 percent), while the percentage of students with prior REU experience has remained low (from 5 to 9 percent). These data show that, in general, PIs have succeeded in recruiting students whose experience at an REU program could make a significant impact on their career choice. In general, these students are from institutions with limited research activities, and thus they are getting a taste of research for the first time in their academic career.

Recruitment Methods For the 2008 and 2009 summer REU programs, PIs were asked to indicate their top one or two most effective student recruitment methods. The choices included: (1) the Internet (website, email, etc.); (2) direct mailings (letters, postcards); (3) media (flyers, newspapers, magazines, TV, radio); (4) conferences, meetings, networking, site visits; (5) campus recruitment office or equivalent; or (6) other methods, which they were asked to specify. In both years, PIs reported that the Internet (n=114 and 117, respectively, for 2008 and 2009) and conferences (n=61 and 57, respectively, for 2008 and 2009) were the most effective recruitment tools.

The PIs reported that their participants found out about their programs through the NSF website (http://www.nsf.gov/crssprgm/reu/list_result.cfm?unitid=5047), which is linked to their own website. Through the NSF website, students are able to access additional information about individual programs, including in a few cases an online application. Other effective recruitment methods included hearing about the program from a fellow student or faculty member (16 PIs mentioned this in 2008 and 30 in 2009), and direct mailings (21 PIs mentioned this in 2008 and 26 in 2009).

Enrichment Activities and Other Program Features To enable student participants to become independent thinkers and effective communicators, the REU programs implement a variety of enrichment activities. According to the survey data from 2008 and 2009, the most common such features of REU programs are scheduled lab meetings, seminars, workshops, and an end-of-program symposium in which students do a poster or an oral presentation of their work. The PIs also indicated that networking

and social events are part of the program (97 percent reported this for 2008 and 99 percent for 2009).

These activities are commonly viewed as enhancing student skills in communication and critical thinking, and helping them to develop a cohort experience. In addition, a good number of programs include a journal club, GRE preparatory courses, and field trips. A surprising finding is that fewer than 20 percent of the PIs indicated that their program included ethics training (20 of 124 programs in 2008 and 24 of 131 in 2009). In general, the programs' enhancement activities, together with an intensive research lab experience, allow the students to derive greater benefits than just joining a lab. In fact, many programs recognize these additional benefits and include non-REU Site participants, such as students supported by an REU supplement, in the REU program activities.

Over the course of four years, the average number of weeks for the program has remained constant at ten. Very few programs are conducted in foreign locations and that number has decreased over time (from seven to four, respectively, for 2006 and 2009). The surveys also revealed the main fields of research undertaken by all of the REU participants (Table 2). Although the combined 2,452 REU participants from 2008 and 2009 represented at least 19 subfields within the biosciences, the majority of the participants conduct research or use tools in molecular and cellular biology; (n=191, n referring to PIs indicating this as the main subfield of research undertaken by their participants). The next four most represented fields in the REU program include animal biology (n=164), microbiology (n=147), and environmental and conservation science (n=150). Overall, the REU programs are increasingly becoming multidisciplinary, involving projects in chemistry/biochemistry (n=126), geosciences (n=54), and other disciplines. These data reflect the broad range of scientific interests represented in the REU program.

Preferred Measurements of Program Success PIs use some type of evaluation so that they can continue to improve their programs and determine their relative effectiveness in providing a high-quality research experience. In addition, PIs track the career progress of former participants. When asked to list up to three metrics they use to

Table 1. Demographic profile of REU Sites' participants. The total number of students in the REU Sites programs is designated as *n*.

| Demographic Profile | 2006 | 2007 | 2008 | 2009 |
|------------------------|------|------|------|------|
| Total, <i>n</i> | 1068 | 1095 | 1196 | 1256 |
| African American | 17 | 18 | 15 | 17 |
| Hispanic | 18 | 18 | 21 | 22 |
| Native American | 5 | 5 | 5 | 6 |
| Pacific Islander | 2 | 2 | 2 | 2 |
| Person with disability | 1 | 1 | 1 | 1 |
| Asian | 6 | 7 | 6 | 6 |
| White | 52 | 48 | 50 | 46 |
| Male | 36 | 38 | 36 | 37 |
| Female | 64 | 62 | 64 | 63 |

measure program success, the 2009 PIs most frequently mentioned graduate school attendance ($n=66$) and participants' general satisfaction with the program, which were noted by 66 PIs. Getting a student's name on a publication was the next most-used metric ($n=47$), followed by completion of research reports ($n=32$). The PIs also use faculty or mentor evaluations ($n=30$), participants' attendance at professional conferences ($n=26$), entrance into a science or education career ($n=24$), completion of a degree ($n=16$), and increased confidence ($n=10$) as metrics to gauge program success.

Similarly, data from the 2008 survey revealed that the PIs viewed graduate school attendance ($n=77$), student publication/presentation ($n=64$) and participants' general satisfaction with the program ($n=54$) as their top three measures of program success. All of the REU sites surveyed in 2008 and 2009 utilized multiple metrics to assess program success.

Summary and Conclusions

Data collected from our surveys revealed the following very interesting results.

1. The REU Sites programs supported by the NSF Directorate for Biological Sciences engage a very diverse group of undergraduates, with more than 40 percent of participants annually coming from groups traditionally underrepresented in science. In summer 2009, approximately half of the participants were members of traditionally defined underrepresented

groups. It is interesting to note that all racial and ethnic groups are represented, including non-traditional students (30 years or older) and persons with disabilities. Among the racial and ethnic groups, our data show increasing participation by Hispanic students, a result that is consistent with the growing numbers of Hispanic students matriculating in college (The Pew Hispanic Center, 2010). To ensure that disabled students are able to participate in the REU program, a small supplemental grant is typically provided by NSF. PIs report that many of their former participants enroll in graduate programs in the biosciences. Participation in an REU-type program is becoming increasingly important for students applying for competitive graduate programs, as well as for those seeking funding opportunities such as the NSF Graduate Research Fellowship Program (NSF Solicitation 10-604).

2. Although PIs can recruit from their own students, the number of participants who come from the host institution is relatively small. The majority of students who participate are those who come from outside the host institution (85 percent on average) and those who come from a non-PhD institution (approximately 60 percent). In addition, many PIs are selecting students whose participation would be more likely to impact the students' career choice. Only 5 to 9 percent of students in the program have had a prior REU experience.

3. There is an overwhelming demand for the REU program. With a total of more than 21,000 applications received by the sites in 2009, PIs are finding it challenging to sort through the myriad applications from talented students. Other than increasing funding for the program, creative ways need to be developed in order to manage the large number of applications and the alarmingly low acceptance rates. In very unusual and limited situations, PIs have received additional supple-

Table 2. Main fields of research undertaken by REU participants in summers 2008 and 2009 combined, as indicated by PIs.

| Field of Research | Number of times indicated by PIs |
|--|----------------------------------|
| Animal Sciences | 164 |
| Bioinformatics | 90 |
| Biotechnology | 60 |
| Chemistry/Biochemistry | 126 |
| Engineering | 27 |
| Environmental and Conservation Science | 150 |
| Evolution | 81 |
| Genomics | 109 |
| Geosciences (marine, atmospheric, earth) | 54 |
| Mathematics and Computational Biology | 29 |
| Microbiology | 147 |
| Molecular and Cellular Biology | 191 |
| Nanotechnology | 21 |
| Organismal Biology | 113 |
| Physics | 19 |
| Plant Sciences | 136 |
| Social, Behavioral and Economic Sciences | 28 |

mental funding from NSF to support students whom they find difficult to reject.

4. The typical participant is female, reflecting the large numbers of women enrolled in undergraduate programs in biology (National Science Foundation, 2009). More students are being accepted who have completed a required set of courses, and the majority of REU participants are rising juniors or seniors. In biology, a small, yet significant, number (10 percent) are students who have just completed high school or their freshman year in college. This young group is seen as more likely to be influenced by the REU experience, since many of these students have not yet decided on a career.

5. A typical REU Sites program is 10 weeks long, with strong interaction between faculty/mentors and students outside of the research activity. PIs report that their programs include enrichment activities such as seminars, field trips, and student symposia.

Many programs offer opportunities for cross-disciplinary research, and in some instances, biology majors work side by side with their non-biology peers. A surprising finding was the small number of PIs who reported training in ethics and the responsible conduct of research (RCR) as part of their program. Such training is now required for REU Sites whose NSF awards started after January 2010, a requirement consistent with the America COMPETES Act (ACA, Pub. L. No. 110-69).

6. There are very few REU Sites in foreign countries, and the number of these programs decreased over the four-year period of the study. Although a few Sites send individual students abroad, the number of programs whose primary activities are based abroad has dwindled from seven in 2006 to four in 2009. This trend is not consistent with the increasing globalization of science.

7. PIs report that the linking their own website to the NSF REU website -is an effective method for recruiting students. Individual programs' websites provide students with information about the programs and allow them to seek programs that are relevant to their interests. A few PIs use their websites to receive online applications, making it possible for students to easily apply to them. The NSF REU website also provides an email contact for each PI or program director.

8. Another surprising finding is that despite the huge recruitment success of REU PIs, diversity was not one of the metrics they considered in measuring success of their own program. Although PIs collectively are doing an outstanding job at recruiting a diverse set of participants, they view participants' progression into graduate programs and student publications and presentations as the most important metrics for measuring success of their program. A large number of PIs also uses general program satisfaction expressed

by students (and sometimes by mentors) as a measurement of success.

PIs interested in seeking funding from NSF should note the general characteristics of the REU program described in this article, and design their proposal in the context of increasing the numbers and diversity of students applying to the program (including possibly encouraging applications from veterans and persons with disabilities). Potential PIs also should consider the need to introduce younger audiences (high school graduates and freshmen) to the program. The increasing trends toward cross-disciplinary research, more quantitative biology, and international/global collaborations should also be considered. Proposals that provide cutting-edge research projects for students, especially in a collaborative environment, would be consistent with the direction in which biosciences are heading and with the recommendations of studies done by the National Research Council (National Research Council, 2009 and 2010) and the American Association for the Advancement of Science (American Association for the Advancement of Science, 2011).

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Sally E. O'Connor

National Science Foundation
Biology Directorate, Division of Biological Infrastructure
4201 Wilson Boulevard
Arlington VA 22230
soconnor@nsf.gov

Sally O'Connor, a program officer at the National Science Foundation, manages a number of programs, including the REU Sites. She mentored a student intern each summer during the study described in this article.

Lida Beninson, an NSF intern in 2009, graduated from Princeton University in 2002 and currently is a graduate student in integrative physiology and science policy at the University of Colorado at Boulder.

Jessica Koski, an NSF intern in 2008, graduated from Michigan Technological University in 2009 and currently is a graduate student at Yale University's School of Forestry and Environmental Studies.

Erika Villa, an NSF intern in 2007, graduated from New Mexico State University in 2008 and currently is a graduate student in bioinformatics at the University of Texas El Paso.

Ronnie Faram, an NSF intern in 2006, graduated from Oklahoma City University in 2008 and currently is a graduate student at the University of Oklahoma College of Dentistry.