

AC 2008-340: REU SITES: MUCH MORE THAN A RESEARCH EXPERIENCE FOR UNDERGRADUATES

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REU Sites: Much More than a Research Experience for Undergraduates

Abstract

Undergraduate research is one of the most important recommended vehicles to address current educational concerns in Science and Engineering, such as high dropout rates, low graduation rates, and low enrollment in graduate programs. In this paper we describe our experience running an NSF-sponsored Research Experiences for Undergraduates (REU) Site in Computer Science and Engineering (CS&E), an area where these problems have been recently exacerbated and where under-represented minority student groups with important growth rates have had a very low participation. The most important aspects that need to be included in these programs to address these concerns and some other initiatives that can bring additional benefits at low cost are also described. For each of these aspects, successful strategies or best practices are included. Finally, the effectiveness of the program is demonstrated with the results of the program evaluation.

1. Introduction

Over the last several years, the United States has witnessed alarming statistics and trends in graduate and undergraduate enrollment, graduation rates, and participation of minority groups in Science and Engineering (S&E) fields, and in Computer Science in particular. For example, according to the National Science Foundation's Science and Engineering indicators 2006, underrepresented minorities did not enroll in or completed college at the same rate as whites. In 2003, the percentage of African Americans and Hispanics who completed bachelor's or higher degrees were 18% and 10%, respectively, compared with 34% of whites¹. The graduation rate for African Americans and Hispanics in Engineering has remained at 11% over the last ten years². Underrepresented minority students are also less likely than other groups to be enrolled in research institutions and instead, a high percentage of them (47%) enrolled in 2-yr institutions. Regarding freshmen intentions to major in S&E¹, shows that in 2004, although 9% of the students planned to major in engineering only 2%-5% had plans to major in Computer Science. At the graduate level, enrollment in S&E has declined since 2003 mainly as a consequence of the decline observed in foreign students, which declined 12% in Engineering and 23% in Computer Science.

Meanwhile, the country has experienced unequal population growth rates of certain minority groups compared to the rest of the U.S. population. In recent reports^{3,4}, Hispanics are shown to be the fastest growing population in the United States and the largest minority group in the country since 2005. Even though the reports indicate that Hispanics will account for one quarter of the U.S.'s population by 2050³, they also indicate that Hispanics only account for 6, 4 and 3 percent of the bachelor's, master's and doctoral degrees, respectively. Furthermore, they are the least educated major ethnic group, and the group with the lowest graduate school enrollment. The conclusion is that these trends and numbers combined represent serious problems for the United States. In order to maintain the competitiveness and leadership in technology, the U.S.

needs to reverse these trends and provide assistance to the Hispanic population now, since they will represent a large portion of its work force in the near future.

One recommended reform included in the NSF Science and Engineering Indicators 2002 report to meet the challenges of Science and Engineering (S&E) higher education is to increase the involvement of undergraduate students in research⁵. Motivated by these statistics and trends in graduation, enrollment and participation of minority groups in S&E, a Research Experiences for Undergraduates (REU) Site proposal was submitted to the National Science Foundation in 2004 to provide students from under-represented minority groups the opportunity to be involved in a 10-week summer research program in Computer Science and Engineering (CS&E).

After running the REU Site for three years, we can say that these programs are very demanding but at the same time very effective and rewarding. Further, they can be leveraged to obtain additional benefits, and can become much more than a summer research experience for undergraduates. This paper describes our program, its unique characteristics, and its objectives in the next section. Section 3 describes the most important aspects that need to be included in these programs to run them successful and Section 4 includes some other initiatives that can bring additional benefits at low cost. For each of these aspects, successful strategies or best practices are included as guidance for those interested in these programs. Section 5 includes some results of the evaluation to show the effectiveness of the program. Finally, Section 6 concludes the paper.

2. Program Description and Objectives

The title of our REU Site is “A Computer Science and Engineering REU Site for Florida, Puerto Rico, and Latin America”. Compared to other REU Sites, the program is unique in mainly two aspects. First, it is not devoted to a particular theme or topic. Instead, it is fairly open, giving students a broad range of research project options in Computer Science and Engineering. For example, research projects in robotics, computer networks, transportation, computer architecture, data mining, artificial intelligence, security, distributed systems, pattern recognition, and digital image processing have been included. The second unique aspect is that, based on the statistics presented above, the commitment was to recruit the majority of the students from the Hispanic minority group, mainly from Florida and Puerto Rico. In addition, the University of South Florida (USF) committed to bringing at least one student from a Latin American country each year.

Most of the other aspects of the program are fairly standard. The program is run for 10 weeks during the summer semester, usually from the end of May to early August. The program provides each student with a stipend, travel and housing support, and an allowance for meals. During the 10-week period, students are assigned to faculty mentors to work on the research projects of their choice. In addition, several workshops, presentations, and social activities are included in the program. All of this information is available on the program’s website at <http://www.csee.usf.edu/REU/>.

As mentioned before, REU Sites are meant to reduce high dropout rates, low graduation rates, and low enrollment in graduate programs involving undergraduates in research activities. As

such, most REU Sites have similar objectives, as follows:

- **Increase graduation rates.** REU programs are meant to enhance the students' curricular activities to keep them more engaged in their field of study and thus increase graduation rates.
- **Increase recruitment of students in graduate programs.** Students work side-by-side with faculty members on interesting and challenging technical problems and realize the importance of graduate education in meeting these challenges. They also attend presentations describing the advantages of graduate education, the application and admissions process, and available funding opportunities.
- **Increase student involvement from under-represented populations.** The objective is to allow and encourage the participation of students coming from underrepresented minority groups.
- **Better prepare undergraduates for their professional careers.** Students are expected to learn how to use state-of-the-art tools and methods to solve current research and practical problems. Also, they are expected to improve their written and oral communication skills through seminars and formal and informal presentations about their projects.
- **Improve student capability for learning independently.** Faculty mentors provide the students with in-depth information and guidance at the beginning of their research assignments. After that initial phase and once given all the tools they need, students are expected and encouraged to work and learn independently.
- **Help faculty mentors advance their research activities.** Students are usually given specific problems to solve, which are part of bigger research endeavors.

3. Main Components of a Successful REU Site

Although running an REU Site looks like a simple endeavor, it requires more time, preparation, and organization than most realize. A successful program requires careful design and implementation of all of its components. Core components, which are critical to the success of the program, are described in the following subsections, including several implementation possibilities and the ones that provided the best results in our case.

A. Recruitment Plan

Recruitment is perhaps the most important program component. A good recruitment plan is necessary in order to guarantee that the program will benefit those for whom it was designed. Recruitment during the first year of a program is especially challenging, since there is not much time between the time the grant is awarded and the beginning of the program.

There are many strategies that can be utilized in the recruitment of qualified students. The first strategy is to set up a website and advertise it. Advertising the website address can be done in a number of ways. For instance, a flier can be designed to advertise the program on all bulletin boards around campus. Information about the program can also be provided during the normal classes and in meetings of technical societies. E-mails and letters (with the flier attached) can be sent to department chairs and many other known faculty members. The URL of the program can be included in the National Science Foundation's list of NSF-funded REU Sites⁶. In addition,

personal visits to target institutions can be made. Local minority societies, other minority organizations, and internal offices such as the office of recruitment and retention, can be good recruiting vehicles as well.

The recruitment efforts yielded a total of 42, 63, and 73 applications the first, second, and third year, respectively. These are very good numbers considering that only 10 students were to receive invitation letters each year. After analyzing the applications, it was clear that personal contact and the NSF website were the most successful recruitment tools. In particular, the presentations and afternoon-long sessions given to the students of the University of Puerto Rico-Mayaguez were very successful in attracting students from the targeted population.

B. Program Evaluation

Program evaluation is another component that should be included in all REU programs; it is necessary to know if the program’s objectives are being met. Evaluation is also needed to identify areas of the program that require improvement.

Table I. A Program Evaluation Guide.

Objective	Primary questions	Data source	Time frame
Assessment of program awareness and recruitment.	How effective are the methods used to advertise the REU program? How successful are recruitment methods in securing diverse students?	Review of recruitment material and procedures; Review of applications received; Demographic data.	Prior to program.
Assessment of expectations.	What are the faculty members’ and students’ expectations? Were they met? How well the program was organized and delivered?	Survey administered to faculty and students at the beginning and conclusion of the program.	Before and after program to faculty and students.
Assessment of program’s objectives.	Did we increase minority participation? Did the program provide the students with skills and knowledge that they felt could be effectively used in their careers? Have we improved the students’ capability to learn independently?	Collect information about diversity (topics, cultures, places), communication skills, feelings about engineering, preparation (tools, techniques, methods), ability to continue learning and doing research independently.	Before, during, and after program to students.
Assessment of long-term effects.	Is there evidence that the program has had an impact on students’ interests? Did we increase the enrollment in graduate programs?	Is there evidence that the program has had an impact on students’ interests? Did we increase the enrollment in graduate programs?	Follow-up survey 12 months after program to students.

Program evaluation can be done either by the organizers or by an entity specialized in program evaluation. Regardless of who performs the evaluation, it is important to collect information before, during, and after the program. Survey instruments can be utilized for each of these time intervals. Before the program gets started, it is important to collect demographic information and expectations, from mentors and students. Other types of questions are about the application process, factors that influenced their decision to join the program, how they found out about the program, etc. During the program, it is very useful to conduct a short weekly evaluation to identify trends in important aspects of the program as well as to detect problems as they occur. A user-friendly Web application is preferable. Students are asked about their day-to-day

experiences, professional development, and general thoughts about the REU experience on a weekly basis. At the end of the program it is necessary to collect information to evaluate the entire program and determine if the objectives were achieved and if the students' and mentors' expectations were actually met. Here, students are asked questions regarding satisfaction with facilities, services, management, and usefulness of the workshops, presentations and social activities. Mentors are asked about their experiences with the students, the extent to which they were able to advance in their research endeavors, their overall experience, and whether they will participate in the future. Also, open-ended questions regarding positive and negative aspects of the program are included. Finally, it is important to collect information about one year after the end of the summer program to know about the long-term impact on the students' lives and careers. Table I is a sample program evaluation guide. It shows the evaluation objectives, the type of questions that need to be answered, the type of data that needs to be collected, and when this data collection process needs to take place.

The REU Site program evaluation was performed by an independent entity, the USF Center for Research, Evaluation, Assessment and Measurement (CREAM)⁷. Although this option requires additional funds, the program evaluation is conducted by specialists in the field who have a more efficient methodology for collecting, analyzing, and reporting data, and guaranteeing confidentiality. This alternative provides two additional benefits. First, students feel more confident and comfortable providing information to an independent entity rather than the organizers directly, which translates into more and better information. Second, from the organizers' point of view, having an independent entity performing the program evaluation saves a considerable amount of time, not only in the evaluation itself, but later in the elaboration of reports and publications.

C. Projects and Professors

The second most important component is finding faculty mentors and interesting research projects. This needs to be done at the very beginning so the projects can be advertised before the students apply. Projects need to be geared to juniors or seniors and designed so that goals can be achieved in a ten-week period. Depending on the number of students, it might be difficult to find the appropriate number of faculty members available during the summer months. Students need a lot of time and attention from their faculty mentors, especially during the first half of the program. A recommended strategy is to have additional projects and faculty mentors available in case some faculty members cannot work over the summer with these students or students want to change their research projects.

It is very important to fulfill the mentors' expectations and help them with their research endeavors; otherwise, they may not want to participate as mentors in the future. Although it is the mentor's main responsibility to guide the REU student through the research experience, there are several recommendations to increase the probability of a successful experience from the student's and the mentor's point of view. First, make sure you have the mentor's project ahead of time and include the technical requirements in the application form. Second, involve mentors in the selection process. Give mentors the applications of those students interested in their projects, and let them select the three best candidates. Third, address students' concerns and problems during the program. Make sure the students have all they need to perform the assigned project

before they arrive. This goes from technical aspects such as computers, tools, Internet access, books, etc. to administrative aspects such as access to university services and labs, payroll, social activities, etc. In other words, make sure faculty mentors put their time and effort in mentoring the students and not in program details. Fourth, include checkpoints and interact with the students frequently. Make sure students are making progress in their research endeavors and help mentors in addressing problems if they exist. A good strategy here is to include check point progress presentations given by the students. Finally, provide mentors with some sort of gift or token of appreciation. At the end of the program, it is a good idea to give mentors a small gift as a sign of appreciation for their time and effort in the mentoring process. This can be something like a good book, a restaurant or book store gift certificate, a small computer gadget that they want, or similar. More information on how to fulfill mentors' expectations can be found in Labrador and Perez⁹.

D. Social and Educational Components

A number of social and educational activities need to be scheduled. Social activities may vary from REU Site to REU Site depending on the city in which the program is located and the facilities and attractions available nearby. An important factor to consider when planning these activities is that most students come from different geographical locations and usually do not have their own transportation. Even though our students had restaurants, movie theaters, a shopping center, and a recreational park within walking distance or a short bus ride, several other social activities were arranged for them.

Educational and other informational presentations need to be arranged too. Workshops on library research techniques, ethics, poster design, presentation skills, writing research papers, getting into graduate school, obtaining financial support, patents and licensing, and strategies for success in professional careers, are several alternatives. Several of these presentations can be organized as lunch seminars. In addition, it is very important to schedule presentations for the students to highlight their accomplishments. Formal presentations at the middle and the end of the ten-week period, and a final poster competition with small cash prizes were scheduled. Several of these social and educational activities can be enhanced if more REU students are involved. Find out if other REU programs are running at your university at the same time, and coordinate joint activities with these other programs. Also, try to house all the students together.

E. Administration Time

There are a large number of administrative tasks required to run an REU Site. The organization of the workshops, caterings, poster competition, social activities, payroll and reimbursements, housing arrangements, recruitment activities, program evaluation, use of university facilities and services, receiving and registering applications, selecting the students and sending official acceptance and rejection letters, etc., are only some of the tasks that need to be accomplished. The fact that some of the students were foreign students required extra time and effort. In addition to obtaining a visa, these students needed help to obtain health insurance, open bank accounts, and obtain social security numbers. Finally, there are always questions about the projects and technical meetings (the organizers can be mentors as well), and behavioral problems to deal with. In most cases, the amount of time needed to run these programs is underestimated.

However, the program is run with wonderful groups of students that make the entire effort fun, rewarding, and worthwhile. The best strategy is to start early and make a weekly plan of activities. Another good strategy is to log the activities in a to-do list ordered by time during the first year; this to-do list will become extremely useful during the subsequent years.

4. Additional Components

There are other optional components that can be included in an REU Site that could bring additional important benefits at low cost. In the following subsections, three initiatives that point in that direction, the “reverse” international component, the involvement of graduate students as mentors, and the extension of the REU experience, are described.

A. The “Reverse” International Component

Developing a diverse, internationally competitive and globally-engaged science and engineering workforce is one of the goals of the National Science Foundation. As a result, REU Sites can include an international component to send our students overseas. This is the most common strategy, as NSF provides funds to support it. In this paper, a relatively inexpensive, highly beneficial, and not very common alternative is described: the “reverse” international component, or bringing international students to participate in your REU program in the U.S.

In our REU Site, this alternative brings international students from Latin American countries since they easily interact with US Hispanic participants and promotes cultural and academic exchange. In addition to that, this alternative contributes to increasing the low rate of Latin American students in US universities. According to the 2007 Report on International Educational Exchange¹⁹, this rate is not only low (around 5%) but decreasing. Only Mexico and Colombia are in the list of the top 20 places of origin but with a participation of less than 4% of the total number of international students.

To support the international students, NSF allocates around \$7,500 to bring one student per year. However, it can be easily doubled. There is so much interest in Latin American countries about these opportunities that it is fairly easy to find universities that will match the costs, allowing you to bring not one, but two students every year.

The “reverse” international component brings many benefits to the REU Site, the students, and the institutions. First, the students are of prime quality. Most Latin American universities have 5-year programs, meaning that the participants, in their senior years, have taken many more courses than their U.S. counterparts. In addition, the institutions conduct a very careful selection process, and only provide these opportunities to their very best students. As a result, these students are ready to make contributions to the assigned projects right from the start, which also has the side effect of increasing the competitiveness among the students and therefore, the quality of the program. Second, students benefit each other, as a real cultural exchange occurs. Students have the opportunity to expand and share their knowledge, forge new relationships, learn about other cultures and languages, and learn different ways to solve and understand problems. Finally, the institutions also obtain several benefits. A strong institutional relationship is in place after the REU experience, leading to new opportunities for collaboration in academic

and research areas. These collaborations help building more stable relations among communities, nations, and individuals, as they share similar language, culture and values. As an example of these collaborative initiatives, a three-day workshop on wireless sensor networks was taught at Universidad de Antioquia, and a dual degree agreement was signed between USF and Universidad del Norte, in Colombia. These activities not only helped Universidad de Antioquia get started with new technologies and improve its curriculum, but they also opened doors for professor to collaborate on research and other educational activities. At the same time, USF has been able to recruit excellent undergraduate and graduate students. More specifics about the benefits as well as detailed information about finding resources to fund this initiative, selecting the universities and the students, and the evaluation of the “reverse” international component, can be found in Guerrero *et al*⁸.

B. Graduate Student Mentors

Another interesting component is the involvement of graduate students in the REU Site, both as mentors and organizers. As mentioned before, REU Sites are very resource demanding, before, during, and after the program for organizers and faculty mentors. This represents an excellent opportunity for graduate students, who can assist in both tasks. Graduate students can design and maintain the program’s website, receive and organize the applications, send flight itineraries, receive students at the airport, teach students about local places to eat and have fun, and many others. At the same time, graduate students are very useful in the mentoring process. Graduate students know the technical details about the student’ assignment very well and can help them with the tools and methods that need to be used to tackle the problem. Graduate students also have interest in the success of the REU students, as the assignments are usually small technical problems from their own areas of research. The relationship between the graduate students and the REU students creates a learning community with important benefits for the graduate students, the REU students, and the faculty. Graduate students improve their mentorship skills and advance their research, REU students learn more and produce better results, and faculty mentors have better students and products¹⁸.

C. Extending the Summer REU Experience

Although working full time for 10 weeks is a long time, the program is not long enough to produce more tangible or impacting results, such as publishing the students’ research in prestigious conferences and journals. One low-cost strategy to overcome this problem is to extend the REU experience beyond the summer program. Involving the REU students in a part time, 10 hrs/week, REU experience over the subsequent fall and spring semesters is very beneficial to the students and the program, and inexpensive. In order to pursue this initiative, it is imperative that the director of the REU Site established one-to-one relationship with the students’ advisors or mentors in their respective institutions. Although this is very easy to do with the advisors of those REU students coming from the host institution, it is not easy to mentor students and supervise progress if the students and mentors are in different institutions. Consequently, it is imperative to establish such a relationship with the advisors of these students, who will be able to better guide the students’ course load and research activities. Since per NSF recommendations the majority of the REU students must come from other institutions, it is

recommended to pursue this initiative with a small group of students, mostly from your own institution.

5. Results

In this section, basic data to show the effectiveness of these programs in meeting the stated objectives are provided. For example, Table II includes participation data. From the table, it can be inferred that the objective of increasing the participation of under-represented minority student groups, was fully achieved. On average, 73% of the participants belonged to under-represented minority groups. This was achieved, in great part, because of the focused and personal recruiting effort.

Table II. Participation data.

	Year 1	Year 2	Year 3	Totals
No. of applications	42	63	73	178
No. of students accepted	14	14	13	41
Acceptance ratio	33%	22%	18%	23%
Males	10	10	12	32
Females	4	4	1	9
Hispanics	11	9	7	27
African Americans	2	1	0	3
Caucasians	1	2	5	8
Others	0	2	1	3
No. of International students	3	2	1	6
% minority participation	93%	71%	54%	73%
No. of projects	9	12	12	33
No. of faculty mentors	11	8	8	27
No. of graduate student mentors	2	9	6	17

Table III also shows the effectiveness of the program with regard to increasing graduation rates and enrollment in graduate school, even without counting the results from the last year. First, as of today, no student has dropped out of college and 54% of the students graduated. These results may say that the program was effective increasing the graduation rates. Second, 73% of those who graduated are in industry or in academia pursuing a graduate school degree. These results may indicate that the REU program was effective preparing the students for the work force and academia, and also increasing the enrollment in graduate school. To be more specific about this last aspect, three Hispanics and two African Americans joined our Ph.D. program in Computer Science and Engineering at USF, and two more Hispanics are in the middle of the application process. Only four students are currently looking for jobs, and one of them just graduated. The data provided in these two tables, although they may not be statistically significant to make strong conclusions, suggest that the REU program is producing the expected results.

With regard to the other objectives of better prepare the students for their professional careers, improve their capabilities for learning independently, and helping faculty mentors advance in their research activities, a considerable amount of information has been collected from the surveys. The data also appear to strongly support the student’s perceptions that the program has provided them with additional skills and experiences that enhanced their ability to be successful in the engineering profession, and in their capability for learning independently. Similar conclusions were obtained after the first year evaluation. These conclusions and more details about the metrics and evaluation of the pre-survey, weekly survey, and after the program survey are documented in Labrador and Perez¹⁴. Similarly, survey data indicates that faculty mentors are also happy with the research results and with the program as a whole. These results are in part supported by the recruitment of REU students into graduate school and the number of technical publications^{10,11,12,15,17}.

Table III. Student performance.

	Year 1	Year 2	Year 3	Totals
No. of participants	14	14	13	41
No. of students who graduated	12	10	N/A	22
No. of students still in college	2	4	N/A	6
No. of students who dropped out of college	0	0	N/A	0
No. of students who joined graduate school	3	2	N/A	5
No. of students who joined the workforce	7	4	N/A	11
Students looking for jobs	2	2	N/A	4
No. of students applying to graduate schools	0	2	N/A	2

The additional components proposed in this paper were also evaluated, although not as rigorously as the rest of the program, as most of these initiatives were implemented after the first year. The first component, the “reverse” international component was evaluated and its positives results published in Guerrero *et al*⁸. In general, it can be said that this is a low-cost and highly beneficial initiative; the initial results have proven that the “reverse” international component contributes positively to many of the objectives of the program. The U.S. students found the “reverse” international component to be a valuable experience that provided them with a broader and better perspective on education and culture in Latin American countries. From the international student’s perspective, the experience was also highly positive. They did not face any funding, cultural, or academic problems that prevented them from being successful in the program. Finally, from the perspective of the educational institutions, this initiative strengthened the links between them, opening up a series of educational and collaborative research opportunities.

The involvement of graduate students as mentors was also evaluated and the results were published in¹⁸. Overall, involving graduate students in the mentoring process of REU students

was found highly beneficial to the undergraduates and graduate students, the faculty, and the program as a whole.

Finally, extending the REU experience beyond the summer was also found to be effective although difficult to achieve in the case of those students coming from other institutions. Using funds from research grants and the internal REU program in the College of Engineering at USF^{13,16}, several of the USF summer REU students continued their projects in the subsequent fall and spring semesters, and only two students coming from other institutions continued their REU experience in their own institutions with the support of their respective advisors. The interesting point is that most technical publications in prestigious conferences and journals were achieved by these students. Implementing this initiative was not easy though, mainly because funds to support this initiative were not included in the original grant proposal.

6. Conclusions

Research Experiences for Undergraduates (REU) programs are an effective vehicle for involving undergraduate students in university research activities with the ultimate goal of ameliorating the alarming dropout rates, graduation rates, and enrollment in graduate school in Science and Engineering. With a focused recruitment plan, these programs can also be very effective in involving minority students in Science and Engineering, and Computer Science in particular, solving other important national problems. However, these programs must be designed and implemented carefully so that they achieve their objectives. This paper describes the most important components that all REU Sites must have and some other low-cost initiatives that increase the benefits of these programs beyond the ones received by the participants. Finally, the paper includes, for each of these components and initiatives, those strategies that provided the best results.

We believe in the value of these programs for the students, the institutions, and the nation, and hope that this paper will contribute to engage others in REU activities. Running an REU Site is a demanding but very rewarding activity.

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