

A Research Initiative to Close the Gap between Undergraduate and Graduate School in Engineering

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Abstract - Recent statistics indicate a declining population of undergraduate engineering students that continue toward advanced engineering degrees. This steady downturn in the number of graduate engineering students has fueled fears that the future of the nation's manufacturing and high technology industry will be damaged by a severe shortage of skilled engineers unless urgent steps are taken to halt and reverse the decline. In response, The College of Engineering (CoE) at the University of South Florida implemented an internal Research Experience for Undergraduates (REU) initiative designed to provide the student with a valuable research encounter. What has resulted is an important retention in the number of engineering undergraduate students enrolling in our graduate program following their REU experience and a systematic approach to integrate a large number of undergraduate students into the research efforts of the college. In this paper we describe our experience and provide guidance for other interested institutions to implement this initiative. Our initial results show that 64% of our graduates continued toward graduate engineering degrees as a direct result of their research experience.

Index Terms - REU in Engineering, graduation rate, graduate enrollment.

INTRODUCTION

In recent years, we have witnessed a declining number of students enrolling and graduating from undergraduate and graduate engineering programs. According to the NSF's Science and Engineering Indicators 2002, the enrollment in engineering has declined continuously from 1983 (441,000 students) to 1999 (361,000) more than 20% [3]. Furthermore, the National Center for Educational Statistics (NCES) found in 2000 that although 25-30% of students entering college intend to major in Science and Engineering, fewer than 50% completed their degrees within a 5-year period [5].

At the graduate level, fortunately, an InfoBrief recent report shows a continuous increase in graduate enrollment in Science and Engineering fields from 1998 to 2001 [1]. Long-term trends indicate that the proportion of women, foreign graduate students, and underrepresented minority groups in graduate fields of Science and Engineering increased during

the past two decades. Enrollment rose in most engineering fields in 2001 with biomedical engineering gaining the greatest enrollment (11%) followed by computer sciences (10%), metallurgical/materials engineering (8%), and electrical engineering (7%). The only declining field was chemical engineering. However, the 429,492 students reported in 2001 are still below the 1993 peak of 435,700 students. The report shows that among U.S. citizens and permanent residents, whites, non-hispanics is the only category with continued decreasing statistics.

The College of Engineering at the University of South Florida is not the exemption, presenting similar trends. At the undergraduate level, the enrollment increased 3.14% from 1998 to 1999, 2.99% from 1999 to 2000, and 4.02% in the following year. However, it only increased 0.64% in the 2001-2002 period. At the graduate level, after experiencing declines in the enrollment from 1998 to 2000, in 2001 and 2002 our graduate population increased 12.73% and 11.1%, respectively. Looking at the numbers we found that the increase was due to the number of non-resident alien students enrolled in our Master programs and the steady population of students from underrepresented minority groups. However, the population of white males and females has been decreasing since 1996-1997 at a slow but constant pace.

One of the several recommended reforms included in [3] for meeting the challenges of Science and Engineering higher education is to increase undergraduate research. In recognition of these nationwide trends and our own ones, in the spring 2002 the Dean of the College of Engineering (CoE) at the University of South Florida (USF) took an institutional approach supporting an internal Research Experience for Undergraduates (iREU) initiative with the ultimate goal of providing all our undergraduate students with a research experience. After one year and a half of initiated, the initiative has resulted in such a success that recently was formally established as a College program. This paper describes our experience implementing this initiative and provides other schools with valuable information about how to implement a similar program. The rest of the paper is organized as follows. Next section describes the program's objectives. Next, the program is described in more detail. Later, useful recommendations to achieve the program's objectives are included. Results of our initial evaluation and several

examples of REU projects are included next. Conclusions are included in the last Section.

very good skills in different subjects and will produce useful and high quality results.

OBJECTIVES

The iREU initiative was initiated in a very informal manner with the ultimate goal of providing all our undergraduate students with a research experience. Although many universities provide students with capstone courses to prepare them better for the upcoming industrial experience only a few universities provide undergraduate students with alternatives to pursue research activities. While we recognize the importance of the capstone courses, we believe it is equally important to open new opportunities to our students in research and development laboratories and centers, high technology companies, and also, in higher education.

Although the idea of using research as a vehicle to increase the graduation rate of our undergraduates and the enrollment of our students in graduate school was compelling, we included these aspects and some others as the main short-term objectives of the program with the intent of measuring them and evaluate the performance of the initiative. As such, the following objectives were established along with the rationale backing our intuition:

- **Contribute to increase the enrollment in graduate programs.**
We believe that by involving students in our research projects and activities, they will perceive the need for contributions and the opportunity to shape a discipline. This excitement will make students think several years ahead, way beyond their college degree.
- **Help students finish their degrees.**
The iREU program will allow students to obtain state-of-the-art knowledge in a discipline of their choice as well as knowledge about research methodologies, methods, and tools. We believe that this knowledge will make our students more attracted to their discipline and better prepared to succeed.
- **Involve students from minority groups.**
Although we do not impose any restrictions to join the program, we certainly encourage students from underrepresented minority groups.
- **Graduate better students.**
During their iREU experience, students will obtain formal knowledge and practical experience on research methodologies and reporting skills in the form of research papers and presentations. In addition, they will learn new subjects and how to use sophisticated tools to perform their activities. We believe this knowledge will be very useful for all type of endeavors, not for graduate studies and research only.
- **Advance our research activities.**
In addition to all these objectives, professors will also obtain benefits. Our undergraduate students have

THE PROGRAM

The iREU initiative started in the spring semester of 2002 with funds directly provided by the Dean of the College. Since then, the Dean has funded the equivalent to four students per department per semester, including the summer, for a total of 120 students per year (4 students, 6 departments, 5 semesters). Students are hired to work 10 hrs per week and receive an stipend of \$8 per hour. In the following sections, we describe the organization and the informational aspects of the program, which are key aspects for its success.

I. The organization

The organization to run the iREU program is very simple. There is one REU coordinator per department in the College. Currently, the College of Engineering has six departments being Electrical, Industrial, Chemical, Civil, Mechanical and Computer Science and Engineering. Each coordinator has two main responsibilities. On the one hand, the coordinators are responsible for promoting and facilitating the program within their own departments. Promoting is advertising the program to students and professors encouraging their participation. The coordinator is also a facilitator advising students asking for research opportunities and linking them to appropriate professors. On the other hand, the coordinators oversee that their departments are achieving the proposed goals and objectives with the assigned budget. In addition, the coordinators also administrate the entire program, establishing new procedures, programming and organizing events, looking for new funding opportunities, etc. One REU coordinator serves as the link between the program and the Associate Dean for Research who was appointed by the Dean to oversee the program.

There are three important factors that will make the job of the coordinator easier and more effective. Time availability is very important. Many students knock his/her coordinator's office door asking for information about the program and procedures to be enrolled. Associated with this activity is friendliness. The coordinator must be friendly to deal with the number of students and recruit them. In addition, the coordinator must have good relationships with the rest of the faculty to encourage their participation and link students to them.

II. Program information

Information about the program is a crucial aspect and it can be advertised in several ways. In order to get the program started, a web page is imperative. It must contain information about the program, application procedures and forms, research areas per department, professors, etc. To guarantee an always-updated web page, each REU coordinator maintains the information regarding his/her department individually and in a

distributed manner. Our web page, located at <http://www.eng.usf.edu/~schlaf/REU>, also contains information about events and opportunities, published articles about the program, students' works and results. The web page URL will be used extensively by students and faculty and will become the main point of reference for information very fast. After that, the most effective way of publicizing the program is the lecture time. These two pieces of information are crucial to get the program started¹. Once the students are enrolled and talk to their classmates about their current experiences, information about the program disseminates as gunpowder.

There are other effective ways to advertise the program and recruit students. For example, another effective way to publicize the program is through events such as the iREU symposium that we will be referring to later on in the paper. Internal newspapers and magazines are also important media since they are easy to access and they reach all the target population. Also, presentations in technical and professional societies are important vehicles to recruit students. For example, we have given presentations in the technical meetings of the IEEE Computer Society and the meetings of the ACM, the National Society of Black Engineers, Society for the Advancement of Minorities in Engineering and Sciences, and Society of Hispanic Professional Engineers to encourage minority students to participate. Finally, we have also organized lab tours. At the beginning of every semester, we open our labs, give presentations about our research projects and have an interactive session with the participating students to explain in more detail the type of activities they will be involved in if joining the program.

III. Procedures

The procedure to be enrolled in the iREU program is very simple. One form was designed for this purpose where the student is asked to include his/her personal information for identification and payroll requirements. In addition, they include information about the project they will be working on and professor they will be working with. Some optional fields are included to obtain additional personal information such as gender, race, current college level and major, publications and honors, etc., mainly for statistics and evaluation purposes. However, the form is actually filled out after the hiring process is a done deal. Usually, the coordinator helps the student to identify one area among the several areas of research currently being pursued by the faculty and directs the student to the appropriate professor. The hiring decision, budget permitting, is left to the hiring professor. Students discuss research opportunities and qualifications with them. Qualifications are those the individual professor considers as important to be successful in the project, such as certain courses, experience with tools, team working, etc. GPAs are considered as part of the decision process but there is no explicit requirement. We don't want to reserve this opportunity to the best students only since this is a new experience for

them all and students with low GPA can find this an incredible experience and perform exceptionally well.

Once the professor agrees to hire the student, the form is utilized and statistic files are updated to collect information for the accountability of the program. This is a very important task. Statistics will be used frequently to justify/support the investment and show the performance of the program. Enrollment, number of students enrolled in graduate school, enrollment of minority students and students completing their degrees are among the most important statistics since they relate directly to the program's objectives.

IV. Additional recommendations

The success of the program and the achievement of its short and long-term goals is tightly related to funding. Having an initial funding commitment, like the one we have had from our Dean, is very important to get the program started, however, it is not enough. New funding alternatives must be found to increase enrollment, satisfy demand and perform additional activities meant to increase the health of the program and enrich the experience of students and professors. Here, we include some successful ideas on where to find additional funds.

There are internal and external sources of funding. We have been successful in receiving internal funds. For example, we received some funds from the graduate college, honors college, and the vice president for research. The key issue is that these are organizations that will directly benefit from the program. Another place is the office of the President or the Provost. However, these sources will usually require some justification so it is important to have started and run the program for some time and show good statistics before taking this route.

Another form of internal funding is matching. Although we have not made matching a mandatory rule, we certainly encourage faculty to match the funds. In this way the number of students participating can be easily multiplied. Matching is an internal source of funds but it is usually related to external funds. Professors match the funds based on the availability of current grants, in particular NSF grants providing REU supplements. We are in the process of writing letters to individual investigators with NSF grants to encourage them to apply for this type of supplemental funds.

The NSF REU program also includes REU sites. REU Sites are usually focused on a particular theme or topic with a strong intellectual component and a considerable number of students coming from an outside institution where research opportunities are limited [2]. However, they also allow the incorporation of students from the hosting institution. Other federal, state and grants in collaboration with industry can be used to incorporate students into the iREU program.

An interesting recommendation to increase the participation of students in the iREU program and to develop the undergraduate curriculum is an REU course. A very good model to follow is the one found in [4] where the author presents a required capstone course on research. Using this

¹ After this, we actually received more students than we could hire.

TABLE I

STATISTICS FROM SPRING 2002 TO SUMMER 2003 (5 SEMESTERS)

Number of Students	Males	Females	Minority	Still in College	Graduated	Graduate school
118	86	32	25	84	33	21
100%	72.88%	27.12%	21.19%	71.19%	27.97%	17.80%

method, students earn credits toward their degrees and pay for the credits as for any other course. However, they will follow the iREU program application guidelines and procedures as any other regular iREU student and will be considered and accounted as part of the program. In this course, students receive formal education on research methodologies, and tools and techniques to do their research activities. After that formal lecture part, students work directly with the faculty sponsor in their research activities. As a requirement, students present a final report in the form of a conference paper and a presentation.

It is important that every department consider what is the best way and the right time to integrate this course into the existing curricula. This was the latest idea that we had, and as of today, most departments are evaluating when and how to implemented this course. We hope to have enough information in the near future to report about its implementation and results.

We also had a wonderful experience with our 2003 First iREU Symposium, which we are now running annually every late spring semester. Students have the chance to present their works in a poster session and interact with the general public and with the group of judges. At the end, prizes are given to the three best posters and special mentions to other three. A special committee was formed with professors and people from local industry to judge the posters. Judges asked questions to students and filled out an evaluation form for each poster. Several aspects were evaluated such as overall content and importance/impact of the research, presentation skills and clarity of the presentation, time in the program, and others. In order to apply, students were asked to submit an abstract of their research work with a short bio and plans for the future. To facilitate their work, we provided students with templates and examples to prepare their abstracts and posters and also printing facilities to print out their posters. In addition, we created fliers with the call for abstracts that included all information about the event and requirements. The symposium event greatly exceeded our expectations. Thirty five students out of the total of 65 students enrolled in the iREU program during the fall 2002 and spring 2003 semesters presented their posters. Students were extremely well prepared and motivated to win the prizes putting a considerable pressure on the judges.

INITIAL RESULTS

Since spring 2002, we have enrolled a total of 118 students in the program. This is a significant number considering that 1) these 118 students are equivalent to 179 since most students were hired more than one semester, and 2) the funds from the Dean were enough to hire 120 students.

Table I shows the statistics of the program for five consecutive semesters since spring 2002. As it can be noticed, the program so far has achieved its goals. 21% of the REU students come from minority groups and 27% are women. 37% of the students graduated and 24% of them have already joined graduate school either in USF or in other institutions.

This means that 64% of our undergraduates who participated in the iREU program joined graduate school. Of all the participating REU students, only one student has not finished his undergraduate degree. At the same time, the numbers say that a considerable number of the enrolled students (74 or 63%) are still in the College working towards their degrees. More time is needed to make sure that the iREU program is in fact achieving its goals and objectives, however, so far the numbers say that we are going in the right direction.

In addition, the iREU program has been successful at achieving the other objectives as well. Most professors are happy with the results obtained and have been able to advance their individual research projects, and students know that they are better prepared to face the challenges of their future careers, whatever they might be.

EXAMPLES OF STUDENT PROJECTS

In this section we provide a description of several iREU projects as an example of the type of endeavors the REU students have been involved in. In Chemical Mechanical Polishing, an REU student investigated the tribological properties of low dielectric materials as interlayer dielectric materials in semiconductor devices. In this project the student's advisor was looking to improve the processing power of devices with successful integration of low-k materials. In Characterization of Pressure Recovery in Aortic Stenosis, the REU student tested if the reliability of non-invasive measurements could be improved by quantifying the effects of pressure recovery. A fuzzy logic base technique was created and utilized by another REU student to create optimal test case sets for software testing. Another student worked on the development of an electrospray injector source for the preparation of biological and polymeric thin films. These and many other projects related to each of the engineering specialties available in the CoE have challenged our undergraduate students and kept them motivated to continue working toward their degrees and joining graduate school.

CONCLUSIONS

In this paper we describe the experience of the College of Engineering at the University of South Florida implementing an internal Research Experience for Undergraduates program. We provide information about the program, its objectives, how to get the program started, different ways of obtaining funds and additional recommendations we consider essential to improve the program and the experience for all people involved in it. So far, the program has been a tremendous

success and a very gratifying experience for students and faculty. We have enrolled 118 students since spring 2002 (5 semesters) out of which 33 have graduated, 21 have joined a graduate school, and 84 are still working toward their degrees.

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