DEVELOPING AND IMPLEMENTING A SUCCESSFUL RESEARCH EXPERIENCE FOR UNDERGRADUATES PROGRAM: A ROADMAP DESIGNED BY THE ENGINEERING RESEARCH CENTER FOR PARTICLE SCIENCE AND TECHNOLOGY

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Abstract — Engineers recognize the importance of providing undergraduates with multidisciplinary research experiences as part of an engineering curriculum. The National Science Foundation (NSF) supports this endeavor through the Research Experience for Undergraduates (REU) Program. The NSF Engineering Research Center for Particle Science and Technology (ERC) at the University of Florida (UF) is committed to providing UF undergraduates with research opportunities, providing experiences to 350 students. The Center extended this program to non-UF students through the NSF REU program. Program goals include providing interdisciplinary laboratory experiences to undergraduates, improving student competence in a laboratory, and increasing the participation of women and minorities in engineering. The ERC has provided 30 students with a 10-week program for the past three years through the REU program and has developed a roadmap that can serve as a model to other institutions that would like to offer a similar program. This paper describes the program, from project selection, recruiting, and logistics, to program management.

Index Terms — REU program planning, undergraduate engineering education.

INTRODUCTION

Particle technology is a multidisciplinary field that deals with the production, characterization, modification, handling, and utilization of a wide variety of particles, in both wet and dry conditions. Industries impacted by particle handling as a core technology include advanced materials, environmental, chemical, mineral, energy, agriculture, pharmaceutical, and food processing. The NSF Engineering Research Center for Particle Science and Technology was established in 1994 to address the nationally recognized need for U.S. trained engineers proficient in state-of-the-art particulate systems research. The Center has addressed the need for improved training of U.S. engineers over the past five years by establishing a comprehensive education program that includes course work, research experience and exposure to the leading particle technology researchers in the world.

A key component of this program is a strong commitment to undergraduate research. There is broad consensus in the engineering education community that undergraduate research is an important component of the engineering curriculum [1, 4, 8, 10]. A hands-on research experience is believed to better prepare students for graduate school, and perhaps equally important, to motivate them to continue beyond the bachelor's level [6, 9]. Programs that encourage students to pursue graduate degrees in engineering are especially important given trends showing a decline in the number of science and engineering graduate students [5, 7].

The goals of the ERC REU program are:
- Provide interdisciplinary, hands-on laboratory experience in particle science and technology to undergraduate students outside of the University of Florida
- Improve student competence and encourage students to become independent thinkers in a laboratory setting
- Increase participation of women and minorities in particle science and technology related education and research opportunities
- Increase awareness of particle science and technology career opportunities
- Improve students' communication skills
- Enhance student-industry interaction through site visits and tours

The ERC program has evolved over the past three years and has benefited from input from both student participants as well as faculty and graduate student advisors.
Research Project Selection

Research project descriptions are solicited from faculty members in early November. Faculty are requested to choose a project that will give students an opportunity to develop independence in the labs and which will allow the students to achieve meaningful results in the 10 week time period available. Faculty advisors are asked to designate appropriate majors for the projects as well. Each project is also assigned to a graduate student mentor. Faculty and graduate mentors with extensive summer travel schedules are not assigned to REU students. Additionally, mentors are expected to have all materials and equipment necessary for the project available at the initiation of the project to avoid delays.

A sampling of the research projects during the first three years follows:

- Laser Induced Breakdown Spectroscopy (LIBS) Utilizing the Rotating Disk Method in the Detection of Heavy Metals in Oils
- Adsorption of Viruses by Sand and Diatomaceous Earth Coated with Metal Oxides, Phosphates, Sulfides, and Metasilicates
- Development and Implementation of a Charge Coupled Device (CCD) Camera System for Atomic Laser Flux Coatings
- Optimization of Column Floation for Phosphate Beneficination
- Silicon Wafer Cleaning Using a Two-Phase Jet Impingement system
- Influence of Ozone Air Treatment on Growth of Bacteria and Fungi in Air Conditioning Systems
- Primary Nucleation of Gypsum in Phosphoric Acid Medium
- Scale-up Design for Laser Pulse Deposition for Particle Coating
- Nanoscratching of Polyester Surfaces as a Model of Particle Asperity-Induced Wear
- Olivine as a Filter Media for the Removal of Cryptosporidium from Water Samples
- Optical Pumping of Hyperpolarized Xenon 129 for the Enhancement of NMR Signals
- The Effects of Urinary Ions on the Dispersion of Calcium Oxalate Monohydrate in the Presence of Mucin
- Bacterial Adsorption to Apatite and Dolomite for Advancement of Floation Processes
- Surface and Colloidal Properties of Calcium Carbonate
- Investigation of Industrial Dispersants for Silica Stabilization

Each of these projects was completed as part of a research team composed of a minimum of one faculty advisor and graduate student as well as at least one UF undergraduate student working with the REU student.

Recruiting

Recruiting materials are mailed out in January to a mailing list that includes undergraduate coordinators and faculty at schools with significant minority student populations. The program description and an on-line application form is placed on the ERC web page.

Given the decline in graduate enrollments, it becomes even more critical to reach out to those groups that are underrepresented in engineering, women and minorities. A research experience can increase a student’s confidence as a researcher[6], providing them with the encouragement to continue their education. Former ERC REU participants confirm this by commenting that the REU “has given me a new confidence in my research ability and in my decision to pursue graduate school” and “I think this program has given me more confidence about what I can do.”

In addition to mailings, specific email announcements to groups such as the Society of Women Engineers, The Women in Engineering Programs Advocates Network, The Society of Black Engineers, The Hispanic Engineering Society, and the American Indian Science and Engineering Society all provide access to these groups of students. Another important connection can be made with the NSF Louis B. Stokes Alliance for Minority Participation in Science and Engineering Program which identifies and trains minority students who are interested in graduate programs.

To ensure adequate representation of women, minority and disabled students in the REU program, active recruiting of these groups of students will ensure an applicant pool that includes representatives from these groups. The ERC has sponsored 30 students in the past three years. Fifteen of these students were women and 15 were underrepresented minority students. Through the use of the recruiting avenues described above, the Summer 2000 application pool of 75 includes 61% female and 39% minority students.

Applicants are required to submit an application, two letters of recommendation, and a transcript. Additionally, and of paramount importance, they are asked to write a letter of interest. Given the interdisciplinary nature of the ERC program, it is not uncommon to accept a student into a research program that is out of their major, but for many students this is the first placement outside of their home department. The focus on interdisciplinary exposure is consistent with the recognition that in today’s engineering environment, an ability to function in interdisciplinary teams is critical. This is reflected in the ABET 2000 criterion that requires engineering programs to demonstrate that graduates have the ability to work in multidisciplinary teams [3]. Given that this is a new experience for many undergraduates, it is most effective when the student can articulate a specific interest in the program and explain how they plan on integrating it into their career plans. One program participant reflected on this aspect of the program in a 6month follow-up survey and commented “At one
point I could not understand why I should take coursework outside of my discipline. Through the REU program I was able to understand that every discipline holds a piece to the puzzle.”

Applications are screened by the ERC Administration, and then project faculty advisors are asked to review and rank applicants to their project. ERC administrators make offers to those selected.

LOGISTICS

There are numerous logistical concerns in setting up a residential program, including housing, library cards, campus orientation, travel, special programs scheduling, etc. The ERC has developed a timeline that is shown in Table 1 that details the timeframe that we have found works best to ensure that all of the logistical details have been addressed. While each campus has individual needs, this timeline can serve as a checklist for those who are either setting up a new program or enhancing an existing one.

Students in the first year of the ERC REU program were surveyed as to their preference for on-campus housing versus off campus apartment arrangements. They unanimously agreed that on-campus housing was preferred. Prior to arrival, students are provided with the names and e-mails of their suite mates, so that they may contact them and coordinate securing common items for the dorm facility.

PROGRAM COMPONENTS AND MANAGEMENT

A timeline for program activities during the 10 week session are listed in Table 2. The first days of the program are of critical importance to the success of the entire program. Attention must be paid to a thorough campus orientation upon arrival. In addition to an orientation to campus, students meet with their advisors and are given a lab tour on the first day. The morning of the second day is a lab safety workshop presented by the UF Office of Environmental Health and Safety. Students come to the program with a wide range of previous lab experience and it is important to establish an acceptable level of safety training prior to beginning work in the lab.

The primary activity of the summer is the research work being conducted by the student. However, additional activities that foster the professional development of the students are also included. These include tours to industrial sites, and oral and written communications workshops. The students give an oral presentation and submit a paper at the end of the summer. A three-month REU calendar is provided to both the student and the mentors on the first day, so that it is clear when the student is available for research and when they will be participating in other program activities. It is important that faculty understand that the professional development components of the program are integral to the total REU experience, and that the student is expected to attend these events.

The ERC Associate Director for Education and Outreach oversees the REU program. It is highly recommended that an additional person be included to handle many of the day-to-day details. The ERC has employed a graduate student in this capacity and this has been successful.

### Table I

| REU PreProgram Time Line |
|---------------------------|
| **September 1** |
| Decide on dates for summer |
| Secure Housing |
| **November 1** |
| Solicit projects from faculty/post docs |
| **November 10** |
| Projects descriptions due |
| **November 15** |
| Send promotional materials for printing |
| **December 1** |
| Information to web master |
| **January 2** |
| Web page/application up |
| **Program advertisement mailings** |
| **February** |
| 6 month follow-up survey for last years REU |
| **March 1** |
| Deadline for applications |
| **March 13** |
| Start making offers |
| **Send packet:** |
| - Letter |
| - Housing brochure |
| - Send roommates names |
| - Forms to complete |
| - City information and brochure |
| **March 20** |
| Finalize participant list |
| Notify faculty |
| **April 1** |
| Begin scheduling |
| - Communications workshops |
| - Industry tours (rent vans) |
| - Ethics workshop |
| - Social Activities |
| - Lab safety workshop |
| - Group meetings/tours |
| - Prepare evaluation forms |
| - Make arrangements for stipend and other financial matters |
| - Make summer calendars |

MENTORING

Mentoring is widely accepted to be a valuable relationship for students and it’s importance is highlighted by an annual awards for excellence in mentoring conferred by the President of the United States [2]. It is thought to be particularly beneficial to those groups that are traditionally underrepresented in engineering. All REU students are not only assigned to a faculty advisor, but are also assigned a graduate student mentor. This mentor can be a valuable role model for REU students who are considering pursuing a graduate career.

The graduate mentors are encouraged to communicate with their REU student prior to their arrival on campus to provide...
them with readings and other materials to help them come prepared and ready to begin work. This facilitates a smooth transition into the lab upon arrival and maximizes their research time here.

TABLE II
REU PROGRAM IMPLEMENTATION

| Week 1 | • Orientation  
|        | • Lunch with faculty and mentors - expectations for summer  
|        | • Survey 1  
|        | • ID cards  
|        | • Send library memo  
|        | • Distribute maps of campus  
|        | • Tour of campus - library, food, pools, gyms, student center, lab facilities  
|        | • Lab safety workshop  
| Week 3 | • Industry Tour  
| Week 5 | • Survey 2  
| Week 6 | • Faculty and mentor survey 1  
| Week 10| • Industry Tour  
| Week 11| • Faculty and mentor survey 2  
|        | • One year follow-up survey for last year’s REU  
| *Weekly| • Group meetings/tour of individual labs  
| **Throughout the Program** | • Communication Workshops  

PROGRAM EVALUATION

The ERC program has evolved to be a highly successful component of our Outreach Program through the input received from both students participants and faculty and graduate student mentors. A multi-faceted evaluation program can provide program managers with the information necessary to ensure that the needs of all of the participants are being met. The ERC has a program that consists of written survey at program entry, mid-program, end-of program, six-month follow-up, and subsequent annual follow-ups. The initial survey evaluates the recruiting and orientation process. It provides valuable information regarding which avenues are the most effective at recruiting students. The mid-program survey is an opportunity to monitor progress in the lab and satisfaction with the mentoring relationship. This identifies potential areas that need to be strengthened or improved. The final survey is an opportunity to evaluate satisfaction with the tours, workshops, and logistical arrangements. In all cases, in addition to scaled statements that the students are asked to rate, students are also given open-ended opportunities to offer suggestions and comments.

In addition to written surveys, students are also questioned during informal debriefings which provide additional information. This evaluation has provided useful information in each of the three years, but was most helpful in the first year. Based on suggestions from both students and faculty, program elements were modified which resulted in a stronger program in subsequent years.

Short term benefits of the program that have been reported include increased communications skills upon return to campus, an appreciation of research, increased confidence, and a refocusing of career goals. Sample comments include:

- *It has definitely led me to decide to continue to pursue a career in the science arena.*
- *It has given me a taste of what research is like. Research is something I feel that I can do.*
- *Because of the experience I decided to change my major to chemical engineering, which will provide a better background for my career.*
- *Through the research and workshops, I gained confidence in my technical abilities.*

The 1999 ERC REU group included students from Columbia University, The University of Michigan, Rensselaer, Texas A&M, Florida A&M, Southern University, The University of Mississippi, The University of Puerto Rico, and Rose Hulman Institute. The group is pictured here on a field trip to PCS Phosphate Industries in White Springs, Florida.

- *I’ve decided to pursue a doctorate degree after college.*
- *I plan to continue my education.*
- *The REU solidified my hope to pursue graduate studies.*

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I was involved in an REU program at Penn State this past summer and the combination of the two has led me to believe I will eventually pursue an MS and PhD.

After this summer I finally feel that my major (ChE) is right for me. Now I am beginning to work on my thesis and it helped to have a little research experience already.

Faculty and graduate mentors have been very satisfied with the program. Each year, ERC faculty who have participated in the REU are asked if they would like to participate the following year. All faculty who have previously sponsored an REU student indicated a willingness to continue in the program. The REU program provides faculty with an enthusiastic, fresh perspective and allows them to undertake exploratory research directions that might not otherwise be practical.

Sample comments from mentors include:

- I am very impressed with the quality, independence and enthusiasm of the REU students I have worked with.
- I am very pleased. He is one of the best students I have worked with - motivated and very capable.
- He is a go-getter. Can we recruit him for grad school?
- The program is the best of the best.

A successful evaluation program includes all of the participants, and a well designed evaluation plan can ensure that the program meets the needs of all of the participants.

CONCLUSION

The ERC REU program has been successful at meeting its goals and is well received by faculty and graduate mentors. The timeline for managing the program has been developed to streamline the administration of the program and has benefited from input gathered by the program evaluation effort. The timeline of activities and logistical program elements can be used as a model by anyone who is interested in developing a similar program. Other institutions who are interested in developing an REU program for their institutions can visit the NSF webpage at www.nsf.gov to learn more about how to prepare and submit an REU proposal. For the student participants, there is no question that these types of opportunities are significant. As one former ERC REU participant reflected in her one-year follow-up survey, "I can't really say enough about how UF's REU programs have changed my life".

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