

## NSF-REU Site Program in Membrane Applied Science and Technology

Gerri L. Burke, William B. Krantz, Joel R. Fried

Department of Chemical and Materials Engineering  
University of Cincinnati  
Cincinnati, OH 45221-0012

### Abstract

The Research Experiences for Undergraduates (REU) Site program is one of the oldest and most successful NSF initiatives. Active research experience is an effective way to encourage qualified undergraduates to undertake graduate studies. This paper describes a very successful multi-disciplinary REU Site program at the University of Cincinnati (UC) whose focus is membrane science and technology. During its first two years, this program received 214 applications, made 24 awards, and involved 19 faculty drawn from nine departments and programs spanning four colleges; 50% of the awards were to women and 25% to underrepresented minorities; none of the awardees were UC students. This paper describes the administration, financial provisions, planning, and components of this ten-week summer program. Emphasis is placed on the uncommon features of this REU program that include the following: linkage to the NSF I/U CRC for Membrane Applied Science and Technology (MAST) and NSF Integrative Graduate Education and Research Traineeship (IGERT) program; inclusion of freshman and non-engineering students; effective inter-college participation; strong ethics component; timely program evaluation; technical papers competition; and financial support to present a subsequent paper at a regional or national meeting. Metrics of the program's effectiveness along with student evaluations and comments on the program are also given.

### 1. Introduction

#### 1.1 The NSF REU Program:

The goal of the NSF REU program is “...to expand student participation in all kinds of research – whether disciplinary, interdisciplinary, or educational in focus – encompassing efforts by individual investigators groups, centers, national facilities and others.”<sup>1</sup> The NSF REU program has two components: supplements to new or on-going NSF research grants; and, REU Site Grants based on a proposal to support a larger number of students on projects having a well-defined focus. NSF encourages REU Site programs to involve students from institutions where research programs are limited. REU students must be either U.S. citizens or permanent residents. A significant number of the REU students should be from outside the host institution.

An REU Site program typically involves participation of 10–15 students and is funded at a level of approximately \$100,000 per year, usually for a period of three years. Renewal proposals from

well-administered REU Site programs are encouraged by NSF. REU Site proposals have a submission deadline that is in mid-August. Awards are announced early in the following year.

### 1.2 Focus and Goals of NSF REU Site Program at UC:

In 2002 the Department of Chemical and Materials Engineering at the University of Cincinnati (UC) was awarded an NSF REU Site grant whose focus is membrane science and technology with a particular emphasis on biomedical and pharmaceutical applications. The goals of this REU Site program are the following:

- To provide a motivational research experience for promising undergraduates
- To encourage women, minorities, and physically disadvantaged students to pursue graduate studies
- To expose undergraduates to exciting research challenges in membrane science and technology
- To facilitate the learning of research methods, laboratory skills, safety awareness, critical thinking, problem solving, research ethics, organizational skills, and oral and written communication skills
- To provide an enjoyable and meaningful social/cultural program for the students
- To provide financial support for undergraduate students during the summer
- To couple an undergraduate component with the graduate research carried out in the MAST Center
- To generate significant research results
- To make progress in developing improved and new applications of membrane science and technology

### 1.3 Technical Focus of REU Program at UC:

Membranes are selectively permeable films that permit separation or controlled release of solutes. They are used in separations such as seawater desalination and purifying waste streams; in biomedical devices such as the artificial kidney, hemodialyzer, and membrane-lung oxygenator; in the controlled release of pharmaceuticals, cosmetics, insecticides, and herbicides; in breathable fabrics such as Gortex™; in surgical garments and dressings; and, in fuel cells and battery separators. They are used as barrier layers in breathable contact lenses, food wrappings, and protective coatings. Membranes are integral to biomimetics whereby we seek to mimic the functionality of living systems. Membranes offer particular promise in this 21<sup>st</sup> century since they are the only technology that can separate, deliver, or discriminate in the smallest scale MEMS (Micro-Electro-Mechanical System) devices.

### 1.4 Scope of this Paper:

We begin with an overview of the administration, financial provisions, and components of our REU Site program. We then focus on its uncommon features. We also include some metrics of the program effectiveness. We conclude with our recommendations for coordinating a successful REU Site program and selected feedback from past student participants.

## 2. Administration, Financial Provisions, and Planning Components

### 2.1 Administration:

Professors William Krantz and Joel Fried have served as the Director and Co-Director, respectively, of this REU Site program. Professor Krantz has considerable experience in administering REU Site programs. While at the University of Colorado he was Director for an NSF-REU Site program from 1993–2000. After accepting the Rieveschl Ohio Eminent Scholar Chair at UC in 2000 he collaborated with Professor Fried to establish this REU Site program. Professors Krantz and Fried have received many awards for teaching excellence and service to students. Professor Krantz is a Life member of ASEE and has received ASEE's George Westinghouse, Rocky Mountain Division Teaching Excellence, and Dow Lectureship awards, and designation as an ASEE Fellow. The Co-Directors are responsible for overall program administration, generating faculty interest, and participating in all the activities.

Ms. Gerri Burke serves as the REU program Coordinator. As such, she handles the details of maintaining the REU web site, program advertising, maintaining student files, arranging travel and accommodations, coordinating the educational, cultural, and social programs, administering the evaluation materials, and documenting program activities. She also participates in the student selection process and project assignments. She received the 2003 President's Quality Service Award in recognition of her contributions to this REU and other UC programs.

### 2.2 Financial Provisions:

Each REU student receives a ten-week stipend of \$3,500, room and board on campus, travel expenses up to \$500, and \$500 for laboratory supplies. In addition, we cover all expenses for the seminars, field trips, and cultural events. We also provide at least 50% of the expenses to present a paper on the student's research at a regional or national technical meeting.

### 2.3 REU Program Planning:

Most students learn of our program via the NSF web site ([www.nsf.gov](http://www.nsf.gov)), which is linked to our UC REU web site ([www.alpha.che.uc.edu/mast](http://www.alpha.che.uc.edu/mast)). We update our web site in October and also send advertising materials via email to all chemical engineering and selected chemistry departments as well as other programs. Applications are accepted from students who will have completed at least one year of college and are one or more years from graduating.

In February, we solicit potential REU projects from UC faculty via an email sent to Deans, Department Heads, and to a list of participating faculty. Projects are posted on our web site as they are received, typically totaling around 30. Faculty email addresses, telephone numbers, and photographs are included with the project descriptions to encourage communication.

Students interested in our program must submit their application, resume, transcript, two reference letters, and narrative discussing their motivation for pursuing this REU opportunity by a mid-March deadline. Applicants are encouraged to contact the faculty who have submitted research projects. We received 79 applications in 2003 and 135 in 2004.

The Co-Directors and Coordinator rank the REU applicants and determine by consensus the 12 awardees and first alternates. We strive to achieve gender parity and to include underrepresented minorities. We also make several awards to students from predominantly undergraduate institutions. Awards are announced during the first week of April.

Students are asked to accept their award and rank-order their top three project choices within one week of receiving an offer. Whenever possible we assign a student their first choice of a project. However, in order to involve more faculty, we sometimes make a second or third choice assignment. In our 2004 program ten students received their first and two their second choice.

Table 1 summarizes the students, their college or university, research project, and faculty mentor and department for our 2003 REU summer program. Table 2 provides this same information for our 2004 REU summer program. Although 12 awards were made for both our 2003 and 2004 REU programs, one student dropped out of the program after arriving on campus during each of these years. Note that our 2003 REU program involved 11 students who came from five states

<b>Table 1: Student and Research Projects for 2003 REU Summer Site Program.</b>		
Jaclyn Barrett Butler University	Permeability of Stratum Corneum to Niacinamide as a Function of Water Activity	Gerald Kasting Pharmacy
Kevin Beard U. of New Mexico	Polymeric Membrane Fabrication Molecule-by- Molecule	William Krantz Chemical Eng.
Zachary Dunbar U. of Nebraska	Gas Permeation through Nanoporous Ceramic Membranes	Jerry Lin Chemical Eng.
Donna Haworth Youngstown State U.	Biomimetic Membranes	Rakesh Govind Chemical Eng.
Emily Heirs Louisiana Tech. U.	Constructing a 3-D Ordered Macroporous Silver Film for a $\mu$ OPPS Micro-separator	Neville Pinto & Vadim Guliants Chemical Eng.
Tricia Katz U. of Toledo.	High-Throughput Screening System for Oral Permeation Enhancers	Giovanni Pauletti Pharmacy
Brian Kiessling Purdue U.	Protein Fouling During Microfiltration	Chia-Chi Ho Chemical Eng.
Nicholas McDonald Rose-Hulman Inst. Tech.	Role of Temperature in the Development of the Two- Layer Preservation Method	Ronald Millard & Horacio Rilo Pharmacology/Cell Biophysics & Surgery
Jill Mecklenborg DePauw University	Biomembranes for Composite Tissue-Engineered Constructs	David Butler Biomedical Eng.
Kimberly Ortiz Louisiana Tech. U.	One-to-One Templating of Sugar Nanostructures	Carlos Co Chemical Eng.
Michael Tranter Rose-Hulman Inst. Tech.	Electrical and Chemical Probing of Cell Membrane Proteins in Heart Muscle	Ronald Millard Pharmacology/Cell Biophysics

and 10 colleges and universities, seven of which were predominantly undergraduate institutions; these students were mentored by 12 faculty drawn from six departments and programs. Our 2004 program involved 11 students who came from nine states and 10 colleges and universities, four of which were predominantly undergraduate institutions; these students were mentored by 14 faculty drawn from eight departments and programs.

**Table 2: Student and Research Projects for 2004 REU Summer Site Program.**

Erin Boutwell Virginia Commonwealth U.	Chemoattracted Cell Migration for Meniscus Tissue Engineering	David Butler Biomedical Eng.
Ingrid Cobb Mt. Holyoke College	Sorption and Permeation of Moisturizing Agents in the Skin	Gerald Kasting Pharmacy
Brian Kiessling Purdue U.	Protein Fouling During Microfiltration	Chia-Chi Ho Chemical Eng.
Brian Kirk Washington State U.	Biodegradable Polymers for Drug and Gene Delivery	Soon-Jai Khang Chemical Eng.
Hilda Kriel U. of Texas	Non-Viral Delivery of Therapeutic Genes to Cardiomyocytes	Keith Jones Pharmacology/Cell Biophysics
David Lally Vanderbilt U.	Effect of Microgravity on O <sub>2</sub> Dependent Transcription Factors in Endothelial Cells	Rupak Banerjee Biomedical Eng.
Arup Mallik Ohio State U.	Development of Synthetic - Melanocortin Agonists for Melanoma Prevention	Zalpha Abdel-Malek Dermatology
Kimberly Ortiz Louisiana Tech. U.	Sugar-based Polymerizable Microemulsion Glasses	Carlos Co Chemical Eng.
Luis Salazar U. of Texas	Preparation/Characterization of Biocompatible Silicone Membranes	Steve Clarson, William Krantz & David Mast – Materials Sci., Chemical Eng., and Physics
Xiao Jing Wang Northwestern	Gas Transport in Nanoporous Membranes	Jerry Lin Chemical Eng.
Roger Wiltfong Rose-Hulman Inst. Tech.	Identification of Novel Proteins in a Genetic Model of Heart Failure	Ronald Millard & Paul Rosevear Pharmacology/Cell Biophysics and Molecular Genetics

After the project assignments are made, the faculty are requested to send background materials on the project to the student. We also ask them at this time to order any special equipment or supplies needed for the student's research so that the student is not delayed with his/her project.

The students arrive in mid-June and are met at the airport by the Co-Directors when necessary. The Co-Directors and Coordinator are available at the UC dormitories to help the students move into their accommodations. The orientation program consists of the following: breakfast followed by a welcome and introductions; program overview; administrative information; overview of Cincinnati and the MAST Center; lunch; group photo; tour of the Engineering

College; video on laboratory safety; introduction to the computer and library facilities; UC campus tour; and issuing of photo IDs.

#### 2.4 Educational, Cultural, and Social Components:

All REU students are required to attend a weekly seminar program. Our 2004 program involved the following topics:

- Membrane Science and Technology in the 21<sup>st</sup> Century (presented by the REU Director)
- How to read a Technical Paper (presented by the UC Vice-President for Research)
- Research Methods (presented by the REU Co-Director)
- Intellectual Property (presented by the Director of the UC Intellectual Property Office)
- Research Ethics (presented by the Director of the Emerging Ethnic Engineers program)
- Post-Graduate Opportunities (presented by a new female Assistant Professor)
- Critical Thinking (presented by the Associate Head of Chemical & Materials Engineering)
- Mind Your Manners (presented by a female Professor in Cultural Studies)
- Presenting a Technical Paper (presented by the REU Director)

A field trip to the Air Force Museum and Wright Patterson Air Force Laboratory in Columbus also was arranged for the students and their mentors. In addition, arrangements were made for the students to attend the 8<sup>th</sup> International Conference on Inorganic Membranes that was held in Cincinnati. A technical poster competition was held during the last week of the REU program. Cash prizes and award plaques were given to the top three posters at a farewell dinner, which also provided a forum for students, advisors, and REU staff to discuss the highlights of the program and influence on the students' career goals.

The cultural and social program consisted of the following: tour of the Cincinnati Art Museum; raft trip on the Little Miami River; trip to Kings Island Amusement Park; weekly TGIF events; picnic and cornhole tournament; and end-of-the-summer picnic. The raft trip necessarily required teamwork and provided a great bonding experience as shown in Figure 1.



**Figure 1: REU student teamwork during the raft trip on the Little Miami River.**

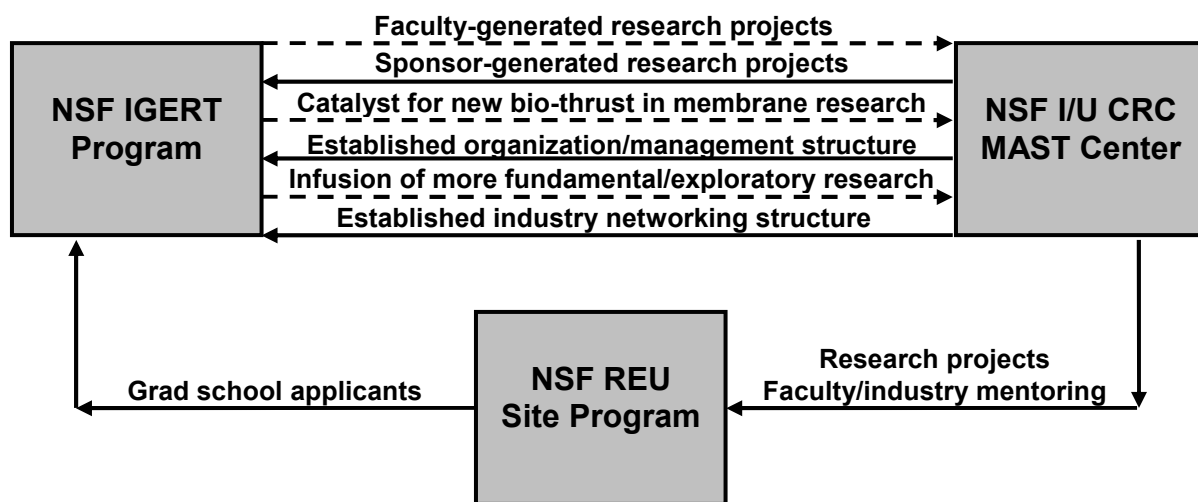
### 3. Novel Features of this REU Site program

#### 3.1 Integration with NSF I/U CRC and NSF IGERT Programs:

A strength of UC's REU program is its linkage to the Center for Membrane Applied Science and Technology (MAST), an NSF Industry/University Cooperative Research Center (I/U CRC), and the NSF Integrative Graduate Education and Research Traineeship (IGERT) program. MAST is the only NSF block-funded membrane research center; its goals are the following:

- To conduct basic research and related developmental activities for the use of membrane technology
- To provide timely and effective technology transfer between the Center and its sponsors
- To promote education in membrane technology

Figure 2 shows how these three programs complement each other. Both the REU and IGERT programs benefit from the membrane expertise, facilities, organizational structure, staff support, industry input, and additional funds made available through the MAST Center. The IGERT program provides a mechanism for initiating faculty-generated research projects to complement the industry-generated research projects in the MAST Center. In addition, the IGERT program catalyzes the new bio-applications research thrust in the MAST Center. The REU program attracts outstanding undergraduates, some of whom apply for IGERT fellowships.



**Figure 2: Schematic showing interaction between NSF REU Site program, I/U CRC MAST Center, and IGERT program.**

#### 3.2 Inclusion of Freshmen:

Most of our REU students had completed their junior year. However, in contrast to many undergraduate research programs, we also include freshmen among our awardees. An REU not only provides a motivational experience for a freshman, but also can lead to very interesting research. Inexperienced students are more likely to pursue an unconventional approach to solving a problem. As such, they can stimulate experienced researchers to think in a different way about a problem. An example is provided by a freshman who came to one of the authors (WBK) to undertake research via an REU supplement that involved adapting video-microscopy

to study the evolution of pore structure during polymeric membrane formation. The student was taking freshman physics while working on this project and proposed using electric fields to eliminate undesirable large pore defects. The author knew that this would not work since he has published a paper that explored this same idea<sup>2</sup>. However, the author did not want to discourage the young man, so he did not tell him about this paper and provided funds for him to explore his ‘ill-conceived’ idea. What subsequently happened is best described by the poem of Edgar Guest:

***So he buckled right in  
with the trace of a grin  
on his face. If he worried, he hid it.  
He started to sing  
as he tackled the thing  
that couldn't be done, and HE DID IT!***

Edgar A. Guest – *It Couldn't Be Done*

Indeed, the student was right and the professor was wrong – wrong in his science but right in his mentoring of a young researcher! This led to a new area of research for the professor and to a U.S. patent<sup>3</sup> and the 1999 U.S. Collegiate Inventor of the Year award for the freshman!

### 3.3 Inclusion of Non-Engineering Students:

We believe that it is important to encourage more U.S. students to consider careers in engineering. Hence, we extend our REU awards to include a significant number of students whose undergraduate major is not in some field of engineering. Our 2003 program included four non-engineering students whose majors were chemistry, pre-pharmacy, biology, and biology/biochemistry. Our 2004 program included two non-engineering students whose majors were chemistry and biochemistry.

### 3.4 Effective Inter-Departmental and Inter-College Participation:

A particular strength of our REU program is its interdisciplinary nature both in terms of student awardees and faculty mentors. This is documented by the data shown in Tables 1 and 2. Figure 3 provides a good testimony to the interdisciplinary nature and diversity of our REU program.

### 3.5 Strong Ethics Component:

NSF REU Site programs may apply for up to \$4,000 in supplemental funding to support a component focused on ethics in science and engineering. The ethics component in our program is coordinated by Kenneth Simonson, an African American who is Director of the Emerging Ethic Engineers program in UC's College of Engineering. This ethics component is structured around case studies. These are presented in a format that involves first providing information on the case, then having the students decide on the ethical solution, and finally discussing the solution that actually was used. The cases involve a variety of ethical issues ranging from honesty in reporting research results, plagiarism, sharing credit for research achievements, acknowledging the work of other researchers, proper administration and use of research funds, environmental responsibility, securing a safe workplace, fair evaluation of subordinates, professional responsibility to the community, protecting your company's interests, and discrimination in hiring, compensation, and professional advancement.



**Figure 3: From left to right: Professor Bill Krantz, REU Director and co-advisor from Chemical Engineering; Alex Anim-Mensah, graduate student co-mentor from Chemical Engineering; Luis Salazar, Hispanic minority REU student from the University of Texas; Professor Steve Clarson, co-advisor from Materials Science; and Jeff Franklin, graduate student co-mentor from Materials Science.**

### 3.6 Timely Evaluation Program:

Timely evaluation is pivotal to running a successful REU Site program. Within the first two weeks of this ten-week program we administer a one-page evaluation that addresses the following questions:

- Have you been satisfied with your research?
- Have you been satisfied with the mentoring?
- Have there been any problems with your accommodations?
- Have there been any problems at all related to this REU program?
- Is there anything that you would like to make us aware of before we visit your lab as part of our routine visit to all the labs?

Any problems identified via this evaluation are addressed immediately. Past problems have included the graduate mentor treating the REU student as a technician rather than as a researcher and lack of adequate contact between the faculty advisor and the REU student.

We also conduct a second evaluation at the midpoint of this ten-week program. The questions included in this evaluation are the following:

- How is your research progressing?
- Are you satisfied with the interest that your faculty advisor and graduate mentor are showing in your project?

- Are you satisfied with the mentoring quality and level of interaction you have with your graduate student mentor?
- Are the equipment, facilities, and supplies available and accessible for your work?
- What assistance can the MAST Center provide at this point to help you fulfill the goals for your research project?
- Is this summer experience helping you to develop your career and/or educational goals?

Problems identified in this midterm evaluation include issues such as inoperative supporting equipment or delays in securing supplies. The REU program Co-Directors and Coordinator have always been able to address any problem identified at this point in the program.

Another evaluation component involves a visit by the REU Co-Directors and Coordinator to each laboratory that is hosting an REU student. We use this opportunity to assess the progress of the research, identify any problems, and to take photos of the REU student and his/her faculty advisor and graduate student mentor.

At the end of the ten-week REU summer program each student must complete a six-page evaluation that addresses the following: program advertisement; orientation program (during the first day of the program); program arrangements (housing, meals, recreational facilities, research assignments); seminar program; research project; field trips; social/cultural program; and the overall program. This comprehensive evaluation can be submitted anonymously if the student so desires to ensure that we obtain an objective assessment of the effectiveness of our program. Table 3 summarizes the responses we received on this six-page evaluation for our 2003 and 2004 REU programs. All of the constructive comments we received on our 2003 program were addressed in our 2004 program and all those received on the latter program will be addressed in our 2005 program.

### 3.7 Technical Poster Competition:

During the last week we host a technical poster competition for our REU students. This is a major event in the College of Engineering and provides a wonderful opportunity for the REU students to showcase their accomplishments. Prior to this poster competition we devote one of our weekly seminars to the topic of *Presenting a Technical Paper*. Five judges are drawn from the faculty in the four colleges that participate in our REU program. The judges are given a one-page guide that allocates 60 points for the technical part (content and comprehension) and 40 points for the non-technical component (organization and presentation). They are also provided with a standard judging form with the components and corresponding points clearly identified. First- (\$200), Second- (\$150), and Third-Place (\$100) cash prizes and award certificates are given. This poster competition offers the additional benefit of preparing the student to present a paper on his/her research at a subsequent technical meeting.

### 3.8 Financial Support to Present a Paper at a Subsequent Technical Meeting:

All students participating in our program are eligible to receive travel funds to present a paper on their summer research at a regional or national technical meeting. Although this seems ambitious for a ten-week summer program, we have found that this is a very effective incentive for the REU students to achieve their research goals. We provided travel funds for two students who

participated in our 2003 program to present papers at technical meetings (North American Membrane Society and Biomedical Engineering Conference).

<b>Table 3: Student Responses to End-of-Program Evaluations for 2003 &amp; 2004. (Number of student responses shown in parentheses)</b>
<b>Was this REU program a good experience overall? Did you achieve your objectives?</b>
Yes (15) – Great/Terrific/Excellent/Good/Definitely good experience (6) – Achieved objective (7) – Did not achieve objective (2) – Did not achieve personal objective (1) – Did not achieve most of the professional objectives (1)
<b>What were the negative aspects of this REU program?</b>
Dormitory accommodations (2) – Transportation (1) – Seminar/Activity Organization (3) – Quality of faculty advisor mentoring (4) – Project focus changes (1) – Facilities (1) – Quality of research project (1) – Time to socialize with other students (1) – Other REU Students (1)
<b>Has this REU program stimulated your interests in graduate studies?</b>
Yes (10) – No (2) – Undecided (3) – No effect (4)
<b>Additional comments for improving this REU program.</b>
Keep it how it is and no one will be disappointed (1) – Make sure that the professors are all active participants in the REU student’s research (1) – Make the REU students more accountable for their research (1) – Require us to turn in progress reports every 2 weeks and even if they aren’t read, it will challenge us (1) – Make the activity and seminar on the same day (1) – Send reading material ahead of time (4) – Order supplies and material ahead of time (3) – Select faculty advisors and graduate student mentors carefully (4) – Require summary of project direction and status early in the program (3) – Give REU students more responsibility (3) – Advisor should plan entire 10 weeks ahead of time (1) – Shorten orientation to one day (3)
<b>What was the most valuable thing you learned about research this summer?</b>
<i>“Nothing ever works the first time, you don’t get the best results until the last 2 weeks, and if both these things occur then you are truly doing research.” – “I got a glimpse at what it would be like as a graduate student in a technical field. This will let me make a much more informed decision about my future upon graduation.” – “It is very important (thinking of grad school) to get a good faculty advisor and a project that you are really interested in because you will be stuck with both!” – “Things don’t always work out the way you’ve planned.” – “It’s hard work and you don’t always get what you expect, but sometimes things aren’t always as they appear.” – “It takes a lot of patience.” – “Research takes a lot of time, patience, perseverance, it’s interesting and I like it.” – “Things don’t always go right.” – “Most valuable was learning what research is all about: Reading papers + Experiments + Discussions + Publishing papers” – “I learned that it’s a lot of joy and disappointments.” – “Nothing works when you want it to...” – “That collaborating with colleagues is necessary for any success on a project. Synergy: 1+1=3.”</i>

The feedback that we received from our past REU students indicates that a continuous effort is needed to improve the program. Since new faculty advisors and graduate student mentors are involved in the program each year, it is inevitable that problems will always arise. Timely

evaluation early in the program can address these problems. It is gratifying that 10 students indicated that this REU program stimulated their interest in pursuing graduate studies. It is also satisfying to read the students' unsolicited comments regarding their research experience. Comments such as "*Research takes a lot of time, patience, perseverance, it's interesting and I like it*" and "*...collaborating with colleagues is necessary for any success on a project...*" suggest that this REU program is accomplishing its goal of exposing undergraduates to the research experience!

#### **4. Metrics of Success**

##### **4.1 Diversity of Participants:**

Figure 4 shows our 2004 REU students, faculty advisors, and graduate mentors, along with the program Co-Directors and Coordinator. The awardees included six men, six women, three underrepresented minorities (two Hispanic and one African American), and four students from predominantly undergraduate institutions. None of these students were from UC. They included students from the following institutions: Louisiana Tech; Mount Holyoke; Northwestern; Ohio State; Purdue; Rose-Hulman Institute of Technology; Syracuse; Texas (2 students); Washington State; Vanderbilt; and Virginia Commonwealth. Two of these students also participated in our 2003 REU program. The average GPAs (on a 4.0 basis) of the students in our 2003 and 2004 REU programs were 3.72 and 3.68, respectively.

##### **4.2 Attracting Students into Careers in Science and Engineering:**

Five of the six juniors who participated in our 2003 program are now pursuing graduate studies in science or engineering. Two of these students applied for graduate studies at UC and one is now studying for his Ph.D. here. Two of the students who participated in our 2003 program applied and were accepted into our 2004 program. The student who won First Place in our Technical Poster Competition in 2003 had intended to study for an MBA. He indicated that as a result of our REU program, he decided to pursue a Ph.D. and is now enrolled at the University of Virginia.

##### **4.3 Students Continuing Their Research Work:**

Two of the students in our 2003 program presented papers on their research at regional and national technical meetings (for which they received a travel award from our program). Two of the students in our 2003 program re-applied and were accepted into our 2004 program. One student from our 2003 program has enrolled in a UC doctoral program to continue his research.

#### **5. Conclusions and Recommendations**

A REU Site program provides a wonderful opportunity to motivate U.S. students to pursue advanced study in science and engineering. The success of an REU Site program hinges on good planning and administration. It is important to attract a large number of faculty participants so that a broad offering of research projects is available for the REU students. REU awards should not be restricted to just engineering students or those who have finished their junior year;

freshman and sophomore students can benefit tremendously and also contribute to an REU program. It is also important to strive for gender parity and participation by underrepresented minorities. Prior to the formal REU program it is important that a dialogue be facilitated between the REU student and his/her faculty advisor and graduate mentor. It is also important to insure that the faculty advisor order in advance any equipment and supplies necessary for the student's research. An additional measure of hospitality in the form of picking up the students at the airport and being at the dormitories to help them move into their accommodations provides a nice 'personal touch' to get the REU program off to a positive start. A blend of technical, cultural, and social activities is critical to creating a meaningful and enjoyable program. In



**Figure 4: Summer 2004 REU Site program group at the University of Cincinnati.**

particular, it is important to have one or two major social events early in the program to facilitate bonding between the students. Evaluation and assessment need to occur several times during the REU Site program; ideally this should take place within the first two weeks, at the mid-point, and at the end of the program. A technical poster competition with cash awards provides a tangible goal for the REU students to work for during the program. Moreover, it prepares the students to present their research results at a subsequent technical meeting. An added incentive is an offer to cover a significant portion of the expenses for the student to attend this regional or national meeting. Finally, it is important to maintain contact with the students after the REU program in order to help them in their professional development and to obtain tangible measures of the effectiveness of the REU program.

It is appropriate to conclude this paper with a few selected comments received from REU students after they returned to their colleges and universities:

*“It's great to know that the REU program will continue there, it was a wonderful experience. I always encourage the undergraduates that I come into contact with to become involved in such wonderful programs as the REU.”*

Donna Haworth (2003 Program)  
Dept. of Chemical Engineering  
Youngstown State University

*“Again, thank you for providing me the opportunity to participate in the REU program last summer. I have benefited a lot from it. Without the REU program, I wouldn't have the opportunity to intern in a company this coming summer. The REU program last summer was one of the best college-related experiences I have ever had.”*

Xiao Jing Wang (2004 Program)  
Dept. of Chemical Engineering  
Northwestern University

*“The opportunity I got offered last summer was my first exposure to a laboratory where I was assigned a project, as a graduate student would, instead of as most undergraduates do. I was able to observe the methods and tools used in the set up of an experiment, as well as the obstacles encountered with research. At the end of the program I had learned a great deal about myself, and what paths I would like to take in my life. The people I met were of great influence to me, and now I am preparing myself to apply to a graduate program in biomedical engineering.”*

Luis Salazar (2004 Program)  
Dept. of Materials Engineering  
University of Texas–Austin

## 6. Acknowledgments

The authors gratefully thank the National Science Foundation for grants EEC-0139438 and EEC-0120823 that are supporting this REU Site program and our Center for Membrane Applied Science and Technology, respectively. The authors also acknowledge Professor Ronald W. Millard of the Department of Pharmacology and Cell Biophysics who helped coordinate this REU program in UC's College of Medicine and who will be taking over as Director in 2005.

## Bibliography

1. *Research Experiences for Undergraduates (REU) Program Solicitation*, NSF 04-584, (2004) p. 4.
2. Shojaie, S.S., A.R. Greenberg and W.B. Krantz, “Use of an Electric Field to Alter Membrane Morphology in a Polysulfone-Polyvinylpyrrolidone Blend,” *J. of Membrane Science*, **79**, 115-122 (1993).
3. Greenberg, A.R., W.B. Krantz, A. Neice and P. Todd, *Apparatus and Method for Controlling Pore Size in Polymeric Membranes and Thin Films*, U.S. Patent No. 6,479,007, issued November 12, 2002.

## GERRI L. BURKE

Gerri Burke is the Coordinator for both the Cincinnati site of the NSF MAST Center and REU Site program at UC. She received a B.S. in psychology in 1994 from the University of Cincinnati. She received the President's Quality Service Award in 2003, which is the highest recognition given by UC to its staff for exceptional commitment and performance.

**WILLIAM B. KRANTZ**

William Krantz is an Emeritus Professor of Chemical Engineering at UC and the University of Colorado. He served as Director of the NSF MAST Center, REU Site program, and IGERT program at UC. He received his Ph.D. in chemical engineering in 1968 from the University of California (Berkeley). He is an ASEE Fellow and received ASEE's George Westinghouse, Rocky Mountain Section Teaching Excellence, and Dow Lectureship awards.

**JOEL R. FRIED**

Joel Fried is a Professor and past Department Head of Chemical Engineering at UC. He is the Co-Director of the REU Site program and new Director of the NSF IGERT program at UC. He received his Ph.D. in polymer science and engineering in 1976 from the University of Massachusetts (Amherst). He received the Faculty Achievement and Outstanding Professor awards in 1994 and 1996, respectively, at UC.