2006-2362: A RESEARCH EXPERIENCE FOR UNDERGRADUATES PROGRAM IN NANO-TECHNOLOGY

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The Research Experience for Undergraduates (REU) at the University of Virginia (UVa) funded by the National Science Foundation (NSF) is a ten-week long summer research opportunity for undergraduate students concentrating in Science, Technology, Engineering and Mathematics (STEM). The main objective is to involve students, targeting those who are underrepresented, in the exploding new nanotechnology field under the direction of faculty at UVa who bring expertise from a wide variety of scientific and technological disciplines. This paper reviews the motivations behind the program's development, discusses the objectives and structure of the program, and finally analyzes the program's impact on the participants' future aspirations.

Background on Engineering Study in the U.S.:

According to the U.S. Bureau of Labor Statistics, the top four projected fastest growing professional occupations in the U.S. through 2008 require training in engineering and science. Of the remaining top ten, only two do not require technological training.[1] However, the overall percentage of science and engineering degrees awarded in the U.S. at the undergraduate, masters and doctoral level has declined from 1966 to 2001.[2] In order to meet this increasing demand for engineers and other technologically trained professionals, the U.S. needs to boost interest in these fields, and increase the pipeline to ultimately graduate more students at all levels in science and engineering.

Research has shown that in the U.S., science, math and engineering fields are not highly desired as academic or career options, in part because there is a serious disconnect between the subject material and its real-life applications.[3] A research experience, especially at the undergraduate level, helps highlight the connection between technical engineering research and engineering's benefits to society. Although laboratory research represents some of the real-life applications of engineering concepts, it is not a core component of many engineering programs. As a study from Arizona State University indicates, this lack of classroom exposure to the professional reality of engineering careers serves as a deterrent to students and graduates.[4] In order to give engineering students a balanced view of engineering, laboratory experience should be included to complement their academic classroom experience. This hands-on component of engineering education can provide an important motivation for otherwise unenthusiastic students to stay in the field and even excel.

According to demographic data, groups that are traditionally underrepresented in engineering are women, African Americans, Hispanics and Native Americans. These groups represent the vast majority of the future labor market but less than ten percent of the engineering workforce.[2] Though the percentage of women and underrepresented populations in the U.S. earning degrees in science and engineering has increased somewhat, the percentage is still far below parity.[5] If the overall goal is to increase the overall number of students pursuing engineering, these traditionally underrepresented groups must be targeted.[3, 6] In addition, including people from outside the traditional demographic would help to introduce new perspectives and lead to a richer more creative environment.[7] However, motivating these groups, and especially women to study

or choose a career in engineering presents a complex challenge. Long the minority in the field, women must overcome several obstacles in order to succeed in engineering and science fields.

Research conducted by the Women in Engineering Programs & Advocates Network (WEPAN) has shown that in a typical engineering program, women students rate their academic self-confidence lower than their male counterparts, feel less comfortable with laboratory equipment or asking questions in an unfamiliar environment and, importantly, tend to perform better in the classroom than in the laboratory.[8] One cause is that that women frequently encounter neglect or hostility in science classrooms. Nevertheless, women engineering students often self-select challenging learning experiences and a heavy workload.[7] Research suggests that guidance of some sort is key for female students already enrolled in an engineering program, especially since the majority do not "join a gender-specific professional group once they have begun their studies."[9] Research experiences present an ideal means of reaching out to under-represented populations. An example of this is the Scholars Program at Arizona State University, a pilot funded by the NSF in 1998 to encourage women to pursue graduate studies. The program paired research participants with graduate students and faculty to provide effective mentoring and role-models to the women participants.[4]

Having done research on women's performance within engineering, Dr. J. McGrath Cohoon of the School of Engineering and Applied Science at UVa recommends several tactics to support women students. These include formalized mentoring, promoting female role models, communicating positive opinions of female students' strengths, and involving women in research.[10] UVa's REU, in cooperation with the Materials Research Science and Engineering Center (MRSEC) at UVa strives to encourage women in engineering by providing all of these support services.

REU Inception and Objectives:

The Research Experience for Undergraduates (REU) began at UVa in 1999 as the Summer Undergraduate Research Program (SURP), under the guidance of the Director of the Center for Diversity in Engineering (CDE – first called the Office of Minority Programs) at UVa. From its inception, the ten-week SURP/REU has been open to all undergraduate students pursuing degrees in STEM fields. It focuses on encouraging underrepresented students (women, African Americans, Hispanics and Native Americans) in engineering by involving them in an exciting hands-on research experience.

These demographic groups have been consciously targeted for several reasons. The first is to augment the overall number of students completing engineering bachelor's degrees by bolstering the participation of minorities in the field. In addition, and perhaps more importantly, producing a diverse pool of students and graduates in engineering ensures the inclusion of a variety of perspectives. As stated above, this leads to a broader focus and greater creativity throughout the discipline. By providing this research opportunity at the undergraduate level, the program aims to de-mystify the laboratory experience, improve participants' confidence about doing research, and inspire a greater commitment to engineering, evidenced by academic performance and further study. Undergraduates who conduct research in a supportive environment are better able to evaluate their inclination for graduate study and are able to understand the type of contribution

they could make to the field of engineering. Encouraging subsequent graduate-level study among REU participants has been a consistent goal of the program and it is therefore important that the research experience includes collaboration with graduate students and post-doctoral researchers in engineering labs. Since the participants work directly with graduate students and post-doctoral fellows as well as faculty, they learn what graduate and post-graduate work entails, while being exposed to multiple role models. The program has been mainly successful in meeting these goals. A detailed analysis of the program is given in the critique section of the paper.

In its initial years, the SURP was funded by Lockheed Martin, the Hughes Network Systems, MERCK, Boeing and the Minority Engineering Program at UVa. Of these, Boeing has consistently provided generous financial support for students participating in the program. Starting in 2000, the SURP received funding from the NSF as part of a proposal for UVa's Center for Nanoscopic Materials Design under the NSF's Materials Research Science and Engineering Center (MRSEC) national network. From 2003 to 2006, the NSF funded SURP/REU, headed by was administered by the CDE. The Center for Nanoscopic Design at UVa provides undergraduate researchers with access to state-of-the art equipment to do ground-breaking research at the molecular and sub-molecular level.

The MRSEC Center for Nanoscopic Design at UVa, established in 2000 with funding from the NSF, has as one of its principal objectives providing undergraduate research experiences in this innovative inter-disciplinary field.[11] The research conducted in the Center for Nanoscopic Design focuses on the assembly of ordered nanostructures on tempered surfaces and involves participants from many engineering fields including material science, electrical, biomedical, chemical and mechanical engineering. Furthermore, advancements in nanotechnology resulting from the Center's research can be tied to potential practical engineering in advanced nanoelectronic design. The Center includes state-of-the-art growth, fabrication, processing and characterization facilities such as a Focused Ion Beam (FIB) for nanoscale surface modification.[12]

Program Structure and Implementation:

Recruitment, Application Review, and Pairing Process

The REU has consistently been marketed to STEM undergraduates through a variety of media. Since 1999, information about the program, including application requirements and the application, has been available online on the CDE's website. Each year, information is sent, first by conventional mail and later electronically, to the Engineering Deans of every engineering program across the U.S. In order to reach the target population, program information is sent separately to the roughly 85 Minority Engineering Program Directors and 70 Women in Engineering and Science Programs. In addition, the program is marketed to the National Association for Multicultural Engineering Program Advocates (NAMEPA) and the Women Engineering Program & Advocates Network (WEPAN).

The application requirements have not changed significantly over the course of the program's operation. Applicants must have completed their second year of an engineering, pre-engineering or science-based program, and applicants are especially encouraged from engineering majors, applied mathematics, physics, biology and chemistry. In addition, applicants must demonstrate

that they are in above average academic standing with a minimum cumulative GPA of 3.0. Applicants are required to submit a statement of their research interest, their resume and two letters of recommendation. Based on these materials, an initial screening of the applications that meet all basic requirements is conducted by the CDE. The basic standards of each year are influenced by the qualifications of the current pool of applicants. Thus the applicants are in competition with themselves and the qualifications for acceptance vary from year to year. The stated research interest is especially important during the application review process since it is used to match applicants with participating faculty. We encourage faculty to select a diverse pool of participants based on their individual laboratory needs.

The faculty members involved in the REU are chosen based on their involvement in the MRSEC program and interest in opening up their laboratories to bright undergraduates and encouraging the next generation of engineering researchers. Once they agree to participate as mentors the faculty begin making preparations for the student participants to join their laboratory for the ten-week program. Faculty are expected to make the research experience meaningful to the participants by supervising their training with any necessary technical equipment and helping them choose a research project that directly relates to the goals of the whole lab. The size of the labs in which students are placed range from two to six researchers. All of the labs include faculty members as well as graduate students and post-doctoral researchers, and sometimes even undergraduate researchers so that the REU participants are exposed to a diverse laboratory team.

In addition to the formal structure of the program, the Center for Diversity in Engineering monitors the participants' progress through regular meetings to discuss the progress in their experiments, being included in the day-to-day workings of the laboratory and are not encountering personal conflicts. These meetings are scheduled by the CDE on an individual and group basis.

Four-Part Structure

The program was restructured to include an ethics course in 2001 when NSF funding supplemented the contributions from industry. The four main components of the REU are all critical to providing participants with a balanced experience. The four components are: independent laboratory research; an ethics course; a Weekly Meeting Series; and a Weekend Excursion Series. The benefits of each activity be discussed separately as well as the synergistic effects of these components working together. Figure 1 (below) shows 2005 REU participants.

Figure 1: 2005 REU participants

Laboratory Experience:
Over the first few weeks the students conduct a literature review related to their research area under the supervision of their faculty-mentor. This is followed by basic laboratory training which includes medical safety and familiarization with equipment relevant to their research experiment. Such equipment includes the Focused Ion Beam, the Scanning Electron Microscope, and procedures for using the Clean Room. Receiving training for this type of equipment is of great value to the undergraduate researchers since the equipment is costly and not frequently made available to undergraduates. While completing whatever technical training they require to work in the lab, participants create a plan of research with their mentors taking into account the relatively short, ten-week, time frame of the research experience. In this period the student must have time to complete the planned research, analyze findings and write up their results. One of the stipulations is that the research be relevant to the faculty-mentor's overall research goals so that the student is involved in a meaningful way. During the course of their research, the participant meets regularly with their mentors which include the faculty member as well as with the graduate students, post-doctoral researchers and even undergraduate researchers working in the lab. The participant must be considered a full-fledged member of the lab-team for the duration of the experience. Since the undergraduates are included in all regular meetings of the lab, they are able to witness the pace at which progress is made and see how a team of researchers works together. At the end of the program, the participants use their results to write a paper and create a poster about their research that is presented at the end of the program. The requirements for the poster are based on what is necessary to present at a professional conference. This is one of the primary mechanisms through which breakthroughs in engineering research are shared with the larger community. After completing the REU at UVa, participants are encouraged to use their posters to present their research at conferences pertaining to their majors. Figures 2 through 4 (below) show 2005 participants working in their laboratories.

Figure 2: 2005 participant working with a nanospheres formed in the polymer, acetone, PVA solution.

Figure 3: 2005 participant studying split endothelial cells.

Figure 4: 2005 participant removing samples of nickel thin-films from the sputter deposition chamber.

Ethics Course:
So that the participants are exposed to the wider context in which their research takes place, they are required to take a class entitled "STS 300: The Ethical Dimensions of Nanotechnology." This two-credit class prepares the REU participants to analyze their summer and future research in terms of its social impact. The class meets three times a week throughout the duration of the research experience and has students examine how their nanoscale research could affect the world around them. At the end of the course, students take an oral exam in which they answer questions such as:

- How does the project potentially affect our way of seeing and experiencing the world?
- Does it serve to commodify knowledge or relationships?
- To what extent does it redefine reality?

Since the research is at the molecular and sub-molecular level, the discoveries can have important effects on the way that society functions. Applications of research on the nano-scale include improving mechanisms for storing data, developing tools to improve medical procedures, creating alternative means of reducing trash or other environmental hazards and building weapons. Therefore, it is not unreasonable to address the ways in which a participant's research could eventually alter society's world-view. The discussion section of the class facilitates the sharing of ideas and provides participants with an outlet for discussing the ramifications of their research projects. This method presents laboratory research as part of an overall approach to engineering that includes thinking in terms of practical application and social benefit as well. Figures 5 and 6 show 2005 participants during the ethics course.

Figure 5: 2005 participants in the ethics course.

Figure 6: Discussion in the 2005 ethics course.

Weekly Meeting Series:

The weekly meeting series exposes participants to important topics related to undergraduate engineering, graduate school and professional paths in engineering. Figures 7 and 8 (below) show participants and presenters from the 2005 weekly meeting series. The series is focused on helping participants plan for the future by presenting ways for them to continue to be involved in research, or how to pursue their engineering interests in the professional world (see Table 1). In addition, the weekly meetings encourage discussion, highlight shared experiences from laboratory research and emphasize the transition to a formal, professional research environment. It is important to give the participants multiple means of interacting with each other. According to J. McGrath Cohoon's research on computer science students at UVa, peer support is an important factor leading to academic success and overall retention within the field.[9]

Figure 7: 2005 weekly meeting discussion.

Figure 8: 2005 faculty presenters.

Table 1: 2005 REU Weekly Meeting Series Schedule

Meeting #: 2005 Date	Meeting Topic
Meeting 1: Monday June 6	Program Orientation
Meeting 2: Tuesday June 14	"Program Overview and Expectations"
Meeting 3: Tuesday June 21	Welcome Address from SEAS Dean James Aylor & Overview Presentations of Summer Research
Meeting 4: Tuesday June 28	"The Graduate Student Experience" with Guest Panel, Graduate Lab. Mentors Invited, and Thank-you Dinner.
Meeting 5: Tuesday July 12	"A Life in Research," with Guest Speaker Robert Hull (MSE Professor, NanoQuest, MRSEC Director).
Meeting 6: Tuesday July 19	"The Successful Graduate School Applicant," with Guest Speakers Kathy Thornton (Assoc. Dean, SEAS Graduate School Admissions) and Hilary Bart-Smith (Professor, Mechanical & Aerospace Engineering).
Meeting 7: Tuesday July 26 at 4:30 in the Rodman Room	Individual presentations for the Bridge Program Students; 3-5 minutes each, PowerPoint presentations are encouraged.

Weekend Excursion Series:

Participants are also encouraged to have fun during their research experience. Since the participants are generally housed on-campus during the REU program, it is important that they have social outlets during the weekends. The excursions aim to expose the participants to a wide variety of activities in Virginia including a visit to Thomas Jefferson's home, Monticello, tubing on the James River and a trip to Busch Gardens in historic Williamsburg (see Table 2, below). Bonding experiences are crucial to success and positive associations. Not only do the participants learn valuable lessons from their peers, but the program also presents an opportunity for them to form lasting friendships with individuals from similar fields. Figure 2 (below) shows 2005 REU participants during the trip to Sugar Hollow.

Table 2: 2005 REU Excursions Schedule

2005 Date	Excursion Destination
Sat. June 18	Hiking to Sugar Hollow
Sat. June 25	Tubing: James River
Sat. July 2	No group activity
Fri. July 8	Clare Quilty at Starr Hill (with Ezra Hamilton & the Naked Puritans)
Sat. July 9	Bus trip to Washington DC
Sat. July 16	Bus trip to King's Dominion
Sat. July 23	Van trip to Busch Gardens
Fri. July 29	Ice Skating
Sun. July 31	Tour of Monticello
Thurs. August 11	Farewell Luncheon

These four main components form a holistic experience through which the participants learn not only laboratory procedures and how to conduct research, but also analytical thinking and team-work. Some REUs focus entirely on the laboratory experience and do not include other types of activities for participants. Other REUs focus only on team-work so that the student participants are not individually responsible for making progress. By providing many interactive outlets for the participants, UVa's REU endeavors to engage the participants on multiple levels. This method stresses not only the importance of individual responsibility and innovation, but the potency of researchers collaborating and working together as a team. This work environment is

complemented by involving students in a very dynamic social atmosphere. Figures 9 and 10 (below) show 2005 REU participants during the trip to Sugar Hollow.

Figure 9: 2005 participants hiking at Sugar Hollow.

Figure 10: 2005 participants at the Sugar Hollow swimming hole.

Impact on Participants:

Participant Demographics

As discussed above, consistent efforts are made to recruit female and minority applicants to the program. As seen in Table 3 (below), women and minorities have consistently made up a significant portion of the UVa REU participants. Once involved, the women and minority participants frequently achieve outstanding results. Some of those are detailed in the section below. Figure 2 (below) shows the 2005 REU participants.

Table 3: REU 2001-2005 Demographic Data Chart

Year	Total Participants	Female Participants	Male Participants	Minority Participants	Female Faculty	Male Faculty
2001	19	7	12	4	1	5
2002	23	10	13	11	0	6
2003	16	9	7	8	1	9
2004	12	8	4	10	0	12
2005	17	11	6	9	2	15

Examples of Projects and Results

REU participants' research frequently leads to breakthroughs in their faculty-mentors' labs. However these results are often not immediately evident. In many cases a participants' research has been published or patented several years after their participation in the program. It is therefore difficult to say what the more recent participants' research may lead to.

In the past, several participants published papers in collaboration with their faculty mentors based on the research conducted during the program after completing the REU. 2001 participant Elizabeth Logsdon published a paper with Professor T.C. Skaylak entitled, "Inverse Micro and Nanocontact Printing."[13] There is a U.S. Patent Pending on the findings with a Provisional Patent Application filed with U.S. Patent Office in October 2003. 2003 participant Lisa Cemke published a paper in 2004, co-authored by UVa Professor Robert Hull, Director of the Center for Nanoscopic Materials Design at UVa, as well as UVa Professors T. Harrell, B. Hosticka, M.E.

Power, and P.M. Norris. The paper entitled, "Selective Deposition of Biocompatible Sol-Gel Materials," was published in the Journal of Sol-Gel Science and Technology, in 2004.[14] Another 2003 participant, Robert Wortman, worked with UVa with Professor J.F. Groves, and UVa graduate student Y. Du to develop an experimental procedure that is in the process of being patented. There is a U.S. Patent Pending with the Full Patent Application filed with the U.S. Patent Office in January 2005 for the "Method and System for Focused Ion Beam Directed Self-assembly of Metal Oxide Island Structures."[15]

Other significant accomplishments include the summer REU research of 2004 participant Joy Chang. Her research led to a UVa Nanotechnology Exploratory Research (NER) grant proposal: "Electronic Devices from Viral and Cytoskeletal Templates," which was funded in 2005 for $130,000.[16] Chang is now working as an National Institute of Health intern in the Exploratory Gerontology Lab.

Undergraduate Elizabeth Logsdon was in her third year of chemical engineering study when she chose to remain at UVa during the 2001 summer and participate in research sponsored by the REU program. Now, Logsdon is completing her third year of Ph.D. studies in Biomedical Engineering at UVa. In the intervening years she has developed novel approaches for nano-tailoring substrates, generated a patent application[17] and mentored two REU students during the summers of 2003 and 2004. She noted during a 2005 interview, "Doing research as an undergrad is exactly the reason I decided on graduate school. Sometimes you just don't know how much you'd love something until you try it."[18] Several of the younger students have gone on to participate in subsequent REU programs at other schools including Izuakolam Akamiro and Courtney Paulding at the Georgia Institute of Technology.

In the final report of her research project, 2004 participant Rebekah Anne Neal compares the REU at UVa to a previous research experience at Georgia Tech where she completed her undergraduate engineering degree. For her, the UVa REU was significant because it allowed her to experience a different laboratory setup and gave her access to high-tech equipment. She said that getting trained to use the Scanning Electron Microscope was very valuable to her because of its relevance to her research area. In addition, she stated that if she had not participated in the REU, she would not have been able to receive training at Georgia Tech because of the associated cost of training to use this equipment. Although Neal stated that she would have preferred to run her experiment several times, she learned from working under the time constraint of the ten-week program and felt that it would add to her ability to conduct research in the future. She also noted that staying up all night working in the laboratory to gather data allowed her to develop camaraderie with the graduate students and other researchers in her lab.[19]

Evaluation Data and Analysis

The following analysis focuses on the recent years of the REU, looking at the students' achievements, satisfaction and accomplishments after completing the program. Students are invited to evaluate the program at the end of each year on a qualitative and quantitative basis. Measures of success include the participants' evaluations, published papers resulting from the research, continuing collaboration with faculty mentors such as the examples mentioned above and pursuit of graduate studies.

The data gathered from the 2004 REU participant evaluations (see Table 4) indicates that there was an overall high level of satisfaction with the program. The Likert rating scale for each question was from 1-5, with 1 as the lowest score and 5 as the highest score. The areas that needed the most improvement were the dormitories and dining facilities. For example, a number of students felt that the hours of operation of the dining halls could not adequately accommodate their research schedules. These issues were taken quite seriously and efforts were made to better meet the students' needs. In 2005, the participants received UVa "Plus Dollars" which could be used at a number of dining facilities that had more extensive hours than the dining hall.

In addition, the ethics course received a lower score than many of the other components, in part because the scheduled time was considered inconvenient by REU participants. There have also been concerns that the material covered in the class is not technically advanced enough and efforts are underway to assess the course's structure and content. It should be noted that in spite of varying levels of satisfaction with particular parts of the program, all of the 2004 participants stated in their evaluation that they would recommend the UVa REU to their peers.

Table 4: 2004 REU Participant Evaluation Data Chart

Category	**Average Rating**	**Standard Deviation**
Accommodations:	2.63	0.601
Excursions:	3.98	0.715
Ethics Course:	3.04	0.785
Ethics Course Texts:	3.41	0.910
Literature review:	4.17	0.718
Orientation to the research laboratory and facilities:	4.25	0.622
Introduction and training:	3.92	0.900
Helpful and meaningful interactions with faculty:	4.43	0.793
Equipment training:	4.67	0.651
Availability of faculty mentor:	4.33	0.888
Interactions with grad students and post docs:	4.42	0.900
Availability of materials to conduct research:	4.00	0.953
Appropriate working environment and space:	4.55	0.820
Involvement in discussions and meetings with lab. mentors:	4.25	0.965
Research discussions with other REU participants:	3.83	1.115
Poster, oral presentation and report:	3.75	0.622
Length of research experience:	3.58	0.793
Average Total Score	3.74	0.792

In 2005, the program began formally assessing participants' progress and satisfaction half way through the program. The information gathered at this time was qualitative rather than quantitative, making statistical analysis difficult. However, the progress evaluations provided the participants with an opportunity to assess their research and overall experience and encouraged them to seek solutions to any encountered problems. There were certain questions in the

evaluation that asked for "Yes or No" responses. The results from those questions shown in Table 5 (see below) indicate a high overall level of satisfaction and progress in the participants' research projects.

Table 5: 2005 REU Participants' July Progress Evaluation Results

Category	% Yes
Students whose goals at July progress evaluation matched original project outline:	88.24%
Students who found the laboratory notebook useful:	82.35%
Students who met regularly with a mentor (the professor or a graduate student or post-doctoral fellow) in their laboratory:	100.00%
Students who found seminars and group meetings interesting:	88.24%

The post-program evaluation survey changed somewhat in format in 2005 and there were fewer numerically-rated questions and a higher proportion of "Yes / Somewhat / No" and qualitative questions. To best represent these results they have been broken down into the two tables below with the first (Table 6a) displaying the responses to the Likert numerically rated questions with 1 indicating a response of "poor" and 4 or 5 (depending on the question) indicating a response of above average, and the second (Table 6b) displaying the percentage responses to the "Yes / Somewhat / No" questions based on the total number of respondents to each question.

Table 6a: 2005 REU Participant Evaluation Data Chart – "Numerically Rated Questions"

Question	Average	Standard Deviation
1. Rate the orientation session on the first day (1-5 scale)	2.62	1.193
2. Rate how helpful your faculty advisor was overall (1-5 scale)	3.25	1.342
3. Rate your experience during the final presentations (1-5 scale)	3.50	0.894
4. How much social interaction did you have with other students in the same REU program? (1-4 scale)	3.19	0.911
5. How much social interaction did you have with REU students from outside the program? (1-4 scale)	2.31	1.014

Table 6b: 2005 REU Participant Evaluation Data Chart – "Yes / Somewhat / No" Questions

Question	% Yes	% Somewhat	% No
6. Was your Faculty advisor accessible?	66.67%	20.00%	13.33%
7. Were the graduate students in the laboratory helpful?	86.67%	6.67%	6.67%
8. Did you interact first-hand with scientists (mentors, post-docs, graduate students and other REU students) for the purpose of research collaboration?	73.33%	20.00%	6.67%
9. Has this REU experience changed your perception of advanced engineering research?	87.50%	6.25%	6.25%
10. Did you learn something from the presentation experience?	100.00%	0.00%	0.00%
11. Would you be interested in conducting scientific research again in the future?	100.00%	0.00%	0.00%
12. Did you feel that the practice GRE was beneficial?	100.00%	0.00%	0.00%
13. Did you have about the right amount of contact with the REU program staff?	100.00%	0.00%	0.00%
14. Overall would you recommend this program to others?	93.75%	6.25%	0.00%
15. Did you feel that creating a web page summarizing your project was beneficial?	85.71%	0.00%	14.29%

Question	% Yes	% Somewhat	% No
16. Do you feel that the Weekly Meeting Series was beneficial?	80.00%	0.00%	20.00%
17. Do you feel that the test presentations to the Bridge program were beneficial?	53.33%	0.00%	46.67%

Unfortunately, most of the Likert rated questions, which give a greater range of responses than the "Yes / Somewhat / No" questions, did not evaluate the research part of the program. From Table 6a it is clear that the first-day orientation needs to be improved, though most of the other categories received relatively high scores on average. Although the mentor-participant question received a decent average score, there was a fair amount of distribution of the scores, with a standard deviation of 1.3416 points (see Table 6a). Although some of the participants did not have as much contact with their faculty advisors as they would have liked, the vast majority had beneficial interactions with members of their laboratory. Of those participants who were less than satisfied with their faculty advisors, all would still recommend the program to others. Significant attention will be paid to monitoring the faculty-participant relationships in future REU's, since they are essential to the success of the program.

The evaluations indicate that roughly 86.67% of the participants felt that their faculty mentors were accessible to some degree, and some 93% felt that the graduate students in the lab were accessible (see Table 6b). In addition, all of the participants did have meaningful relationships with a permanent member of the laboratory (see Table 5), even if their primary contact was not with the faculty member, but with a graduate student or post-doctoral fellow. Depending on the laboratory and the nature of the work being done, the faculty member in charge of the laboratory has more or less to do with the day-to-day functions. In many cases, the graduate students working with that faculty member are responsible for most of the daily operating details, and so it makes sense that in those cases, they would have greater contact with those members of the laboratory than with the professor. In the future, the administrators will make a concerted effort to make this information known to the participants so that they have realistic expectations of their faculty mentors and the other mentors in the laboratories.

The responses to the "Yes / Somewhat / No" questions, shown in Table 6b, confirm that the program is generally meeting its goals of increasing undergraduate access to meaningful engineering research opportunities. Over ninety percent of the 2005 participants indicated that they interacted with scientists for the purpose of research and that the exposure to engineering research altered their previous perceptions of what advanced research entailed. Other indications of success were that all of the 2005 participants indicated that they learned something from the presentation experience, that they were interested in conducting scientific research in the future, benefited from the practice GRE, had the right amount of contact with the administrative staff, and would recommend the program to their peers (see Table 6b). Roughly 86% (see Table 6b) of the participants felt that creating a web-page detailing their project was a beneficial exercise. In addition, by posting their projects online, the 2005 participants made it possible for future applicants to see the types of research they could be involved in and the level of sophistication of the research performed by past participants. Twenty percent of the 2005 participants did not feel that the weekly meetings were useful and the most frequent accompanying complaint was that it took time away from research. Yet, there were also participants who felt that the meeting series gave them valuable insight into engineering graduate school. Efforts will be made in the

upcoming REU to evaluate the weekly meeting series in more detail and thereby determine what specifically participants think would improve that activity.

The component of the program that received the lowest score was the presentation that the REU students made to the entering freshman participating in the CDE's Engineering Summer Bridge program (Table 6b). In the open-ended portion of this question, many of the participants responded that they felt that this was not good practice for their final presentation because the prior knowledge of the Bridge participants was so much lower than that of the peer and faculty audience for the final presentation. However, from the standpoint of the REU administration and faculty, it is a useful exercise to learn how to present to your peers as well as to audiences that know significantly more or less than you about the research subject. Greater efforts will be made in the future to explain this perspective to the participants so that they do not assume that the presentation to the Bridge participants is merely practice for their final presentation.

In the 2005 post-program evaluation, the participants had the opportunity to state what they learned from the program. Although these responses were open-ended, they fell into four overlapping categories. These general categories were "Personal / Research Interactions," "Research Knowledge," "Graduate School Knowledge" and "Presentation Knowledge." Table 7 (see below) shows the responses, organized by these categories. In the table, for each of the sixteen respondents, an "X" under a given heading denotes that that category was indicated in the participant's evaluation. As is evident, all participants gained research knowledge, and most felt that they improved their presentation skills and benefited from the personal and research interactions. However, a smaller proportion, only 68.75% specifically stated that they acquired new information or a new perspective on graduate school. In the next evaluations, there will be at least one question specifically about graduate school so that we can determine if this lack of responses about graduate school was caused by the open-ended nature of the survey which mentioned the other categories more explicitly at various stages, or whether the program does not adequately acquaint the participants to graduate school.

Table 7: 2005 REU Participants' Stated Program Benefits

Category	Percentage Stated Benefit
Personal / Research Interactions	81.25%
Research Knowledge	100%
Graduate School Knowledge	68.75%
Presentation Skills	87.5%

The more qualitative responses from the post-program evaluation are also useful for a thorough analysis of the participant evaluations, since they give the participants the opportunity to fully explain their responses, as seen in the above discussion. There were cases in which what appeared to be a negative response to some aspect of the program was mitigated by additional or outside variables experienced by the participant. It is important to know all of the factors related to less-than-satisfactory experiences in order to most effectively solve the problem in the future and improve the program overall. For example, one 2005 participant had an overall negative assessment of his UVa REU experience. Although this was due to dissatisfaction with his faculty placement, it became clear from the open-ended portion that this was in large part because the research was outside of the participant's main area of interest. Furthermore, this participant also stated that she/he would recommend the program to peers in spite of the individual experience.

Thorough responses such as this one make it possible for the program administrators to understand participants' reactions and better meet the needs of future participants, in this case by working to improve the student – mentor pairing process.

Table 8: Past REU Participants Pursuing Engineering Graduate School

Year	Graduate School Enrollees	Graduate School Applicants	Total Enrolled in or Applying to Graduate School
2001	6	n/a	31%
2002	9	n/a	39%
2003	7	1	50%
2004	n/a	7	58%

Although the CDE has attempted to track the UVa REU participants, it has proved difficult to place all of the past participants. Based on those who have responded to follow-up surveys on their activities after completing the REU, the following data set was developed (see Table 8, above). Since 2001, the known percentage of REU participants pursuing graduate studies in engineering has steadily increased. In addition, anecdotal feedback demonstrates that participants develop positive connotations about graduate school during the program.

Critique of the REU

Every year, changes are made to the REU based on the reactions of the past participants. These have included changing the schedule of the ethics course, adding or removing particular excursions and trying to better accommodate the on-campus living accommodations. However, overall, the program has met its primary goals: to increase the number of women and minorities continuing in engineering through the undergraduate level and beyond; to introduce undergraduates to the research environment and to build confidence in one's ability to perform research. This conclusion is based on the evaluation data and the results and accomplishments outlined above. In summary, an increase in the numbers of students that are now interested and enthusiastic about pursuing advanced study in engineering heralds progress. The REU is helping to break down the barriers that prevent undergraduates from conducting research and further solidifying a community of young engineering researchers.

One area in which the REU needs improvement is in recruiting female faculty to work with students. There are not many women faculty currently collaborating on the UVa REU (see Table 3). Progress in this area is mitigated by the lack of women faculty currently part of the UVa Engineering faculty. This is also reflective of the low proportion of women in Engineering nationwide. However, female faculty serve as important role models for the participants and it is helpful to the male as well as the female participants to see a gender balance among their mentors. The most important aim regarding the faculty remains to have them serve as supportive mentors for the participants, regardless of gender or ethnicity, since "faculty can discourage women with unthinking remarks or with expectations based on the assumption that men's behavior and experience are the basis for success."[9] It is hoped that the relatively high number of women participants in UVa's REU, will eventually contribute to a higher proportion of women excelling in the field.

As previously discussed, there will be many areas targeted for change and improvement in 2006. These areas include: the accommodations and dining services; initiating the literature review process earlier to facilitate communication between the mentors and the REU participants (this will also ensure that the participants are better prepared when they arrive to start the program); monitoring the mentor-participant relationship; implementing a systematically quantitative evaluation to compliment the largely qualitative evaluation process; altering the structure of the ethics course; and providing additional explanation for various components of the program such as what the participants can expect from the faculty and graduate students, what they can gain from the Bridge presentations. In addition, the CDE will continue to track REU alumni in order to determine the longer-term benefits of the program.

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