# AC 2009-1726: THE INFLUENCE OF A RESEARCH EXPERIENCES FOR UNDERGRADUATES PROGRAM ON STUDENTS' ATTITUDES TOWARD ENGINEERING RESEARCH

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# The influence of a research experiences for undergraduates program on students' attitudes toward engineering research


## Abstract

The results of the second year study of a National Science Foundation Research Experiences for Undergraduates (REU) Site are presented in this paper. The program recruited students nationwide to participate in hands-on experimental research in a mechanical engineering department for eight weeks in the summer of 2008. The program matched 10 students with faculty and graduate student mentors in several mechanical engineering laboratories, including experimental fluid dynamics, micro-sensors, laser micromachining, and advanced manufacturing. Participants attended seminars on experimental uncertainty, planning experiments, and presentation of experimental data. Students also attended field trips to local companies where they met with practicing mechanical engineers.

Applicant surveys were employed to learn about the interests and background of applicants, how they learned of the REU program, and why they wished to participate. Among findings of interest were that one-third of student applicants decided to study engineering during the senior year of high school or later, that student applicants were much more likely to have been influenced to study engineering by family or high school teachers than by high school counselors, and that college faculty played a major role in students' interest in an REU program. The admitted students participated in First Day and Final Day surveys and focus groups. Among the focus group insights were the realization that research often does not provide the "closure" that students would expect from an academic course, an appreciation for the precision that research requires, the importance of research literature to the engineering knowledge base, and the patience required to execute experimental programs. The report also discusses how results from the 2007 study of participants at the same REU site were used to implement improvements in the 2008 program, including a seminar on evaluating graduate programs and applying to graduate school. The paper will also compare and contrast participant responses from the 2007 and 2008 program evaluations.


## Introduction

A National Science Foundation (NSF) funded Research Experiences for Undergraduates (REU) Site was conducted during the summer of 2008 at Southern Methodist University (SMU). This was the second year of the program, the theme of which was "Experimental Methods in Mechanical Engineering." The theme was selected by the PIs because most of the mechanical engineering faculty research programs have an emphasis on experimental techniques. Experimental research is also a "hands-on" activity, which is appealing to many students, such as active learners[1]. Experimental research has also been shown to be effective for improving retention among participants[2,3]. Research laboratories that participated in the program were the Laser Micromachining Laboratory, the Experimental Fluid Mechanics Laboratory, the Research Center for Advanced Manufacturing, the Laboratory for Micro- and Nano-Mechanics of Materials, and the Micro Sensor Laboratory.

A website (http://lyle.smu.edu/REU) was used as the central source of information for prospective applicants. The website included detailed program information including program location, dates, stipend, housing, and dining. The website also included a list of participating research laboratories and projects, eligibility requirements, contact information, required application materials and optional survey forms. The required application materials were an application form, resumé, statement of purpose essay, transcript, two letters of recommendation, and ranked list of at least two preferred projects. The application form requested student contact information, college/university, academic major(s)/minor(s), and GPA. The program was advertised through a promotional email message that contained basic program information and referred potential applicants to the REU website for detailed information. The email was distributed to undergraduate engineering students at SMU, contacts at other universities who previously agreed to distribute the email at their institutions, and the Women in Engineering Program Advocates Network (WEPAN) nationwide list-serve.

Participants were selected from the applicant pool based on their qualifications, interest in performing research, and choice of research topics. Minimum eligibility requirements for the program were sophomore standing or higher, 3.0 GPA, and a major in engineering or engineering science. Closely related majors in the sciences, such as materials science, physics, and chemistry were also considered if the major closely matched a project in which the applicant was interested. Matching of selected participants with faculty mentors was performed by the principal investigators (PIs) based on project preferences indicated by the applicants.

The program lasted eight weeks during the summer of 2008. Since the students were not all working with the same research group, the PIs organized several group activities outside of the laboratory to maintain a cohort experience. The primary activity was a seminar series, presented by the PIs, on various aspects of experimental methods. The titles of the seminars and a brief description of each are listed in Table 1. Seminars were designed to provide students with skills for both the REU experience and their professional careers. Group trips to local companies that employ mechanical engineers in design, manufacturing, or research were also organized. A social event over the Independence Day holiday and the use of living quarters located in a single building were also used to enhance the cohort experience.

Table 1: REU Seminars on Experimental Methods in Mechanical Engineering

| **Seminar Title** | **Description** |
|---|---|
| The Purpose of Measurements | Overview of the types of experiments and their purpose |
| Uncertainty in Experiments | Uncertainty and error in experiments and how to minimize and quantify uncertainty |
| Avoiding Mistakes | Proper planning of experiments; sensor response |
| Written Presentation of Results | Presenting data in graphical and written form; formatting and content for reports, journal articles, etc. |
| Oral Presentation of Results | Poster presentations, conference and meeting presentations, presentation techniques, and time management during presentations |
| Graduate School | Overview of graduate degrees, finding a graduate school, applying to graduate school, finding an advisor, and funding for graduate school |

At the conclusion of the program, students were required to participate in a poster presentation competition. This provided an opportunity to demonstrate what they had learned during their research experience in the laboratory, utilize the presentation and experimental skills obtained in the seminar series, and observe what other participants worked on during the program. The poster presentations also were open to faculty and staff in the school of engineering. Three judges were chosen from the faculty and staff who were not participating as mentors. Posters were judged on formatting, abstract, motivation, diagram of experimental apparatus, key results and data presentation, significance of results and conclusions, and oral communication style. The titles of the student projects were: Development of a Micro-Optical Accelerometer Based on Whispering Gallery Mode, Mechanics of Laser Induced Forward Transfer, Silver Deposition by Laser Induced Forward Transfer, Temperature Measurement for Hybrid Welding of High-Strength Materials, Friction Stir Welding of Aluminum Components, Initial Study on the Accuracy of the Arcam A2 Electron Beam Melting Machine, Evaluation and Modification of an Instron E1000 Machine, Exploring a Firewire Camera, Vortex Ring Evolution at Low Reynolds Numbers, and Thrust Characterization of a Pulsed Jet Engine and Model Rocket Motors.

**Administration and Costs of the 2008 REU Program**

The REU program was administered by the grant PIs, who are both faculty members in the Department of Mechanical Engineering. Administration activities primarily occurred in the spring semester and the summer months in which the students were on campus. Program planning occurred in the spring semester, including development of advertising materials, coordinating room and board plans, reviewing student applications, and communicating with applicants. An estimated 2 weeks were spent by each faculty member in the spring semester for planning activities. In the summer months faculty administrative time was spent on 5 weekly seminars (1 hour each), preparation of the seminar materials (1 week), 3 field trips to local industry (1/2 day each trip + 1/2 day planning each trip), the end of semester poster presentation (1 day), and mentor time with the students working in their labs. In addition to the grant PIs, an evaluator (Dr. Alice Kendrick) from the Department of Advertising developed surveys for applicants and participants, administered on-campus focus groups with participants, and evaluated the results of surveys and focus groups. Her time was estimated to be 50 hours. In addition to the faculty time, costs of the REU program were a $450 per student weekly stipend and $2,167 per student for room and board and a 3 meal per day meal plan.

**Changes to the 2008 REU Program**

Changes were implemented to the 2008 REU program based on the 2007 program evaluation, which was reported in a previous publication[4]. Major changes to the program were the additional emphasis on advertising through contacts at other universities/colleges, addition of a graduate school seminar, and a discussion of student expectations on the first day of the program. The graduate school seminar gave a broad overview of the types of degrees available, the purpose of obtaining a graduate degree, how to apply to graduate school, how to find funding and a research advisor, and how to search for a graduate school. The first day discussion of expectations included an overview of the research environment, expected work hours and behavior, and emphasized the importance of effective communication between participants and research mentors. The PIs also added two additional requirements to the 2008 program: an

uncertainty analysis and final report. The uncertainty analysis was assigned after the completion of the "Uncertainty in Experiments" seminar and required students to perform an analysis related to their research project. This analysis challenged the students to think critically about the research project on which they were working at an early stage. By performing this exercise early in the program the PIs also were able to provide feedback to the students well in advance of their poster presentations. The feedback from the PIs was also useful in providing students feedback from a researcher who was not actively involved in their individual project. The final report required students to summarize their work in a concise and effective manner using the skills gained in the "Written Presentation of Results" seminar.

**Evaluation Method**

Two sets of data are reported in this study. One resulted from an optional applicant profile questionnaire completed by a subset of those who applied to the REU program. The other data were collected from students who were selected for and participated in the REU program. The seven REU student participants who were in their first year of the program completed on-campus First Day and Final Day paper-and-pencil questionnaires, and participated in focus group sessions held on their first and last days. Three of the 2008 participants were in their second year of the program. Their responses are not included in this study.

Both the on-site questionnaires and the focus group discussion guides included items involving program outcomes, perceptions of engineering research, desire to pursue graduate studies in engineering, and evaluation of the REU experience. Question types included dichotomous, multiple response, agree/disagree 5-point scales for directional statements, and open-ended items. Information obtained in the focus groups is used to explain some of the student attitudes and recommendations.

**Applicant Profile**

In addition to their application, students applying to the REU program were given the opportunity to complete a questionnaire designed to measure demographic data; academic profile information; career interests; knowledge of and attitudes toward engineering education, engineering research and workplace issues. In addition, the questionnaire included items about how the applicant became aware of the REU program, so that the site team could evaluate its strategy for recruiting.

Twenty-three applications were received for the 2008 program. Of those applicants, 12 returned the applicant questionnaire. Two of those who replied had previously participated in the REU program. Of the 10 applicants who did not participate in 2007, 6 were male and 4 were female, ranging in age from 19-24 years, with a median age of 20. The academic status distribution was 2 rising sophomores, 4 rising juniors, and 4 rising seniors. One applicant was an ethnic minority and another was an international student. Ten applicants were from the metro area in which the program was located. Activities in high school included science fair (n=6), talented/gifted courses (n=6) and band or orchestra (n=5).

All of the applicants responding to the survey were engineering majors, and engineering was the first choice of major for all. Nine out of 10 said they made their decision to study engineering some time after sophomore year in high school, and one said the decision was not made until the first year of college. Many of the applicants cited family members as influencers in their decision to study engineering. In most cases, a parent, relative or close friend was an engineer. Some reported that science or math teachers influenced them also, but none reported high school career counselors as influencers.

Applicants reported that they had initially heard about the REU program from professors (3), career services or counselors (3), friends (2), Internet searches of universities with graduate programs (1), and the National Science Foundation Web site (1). Six applicants said they were applying for other positions for the summer, all of which involved internships, other REU programs, or research-related work.

**Participant Profile**

Ten participants were chosen for the program, 3 of whom participated in the 2007 program. Five of the participants were female and 5 were from other colleges and universities outside of the host institution. The participant survey and focus group discussion only reports on the 7 new participants. At the beginning of the program, the new participants included 1 rising sophomore, 4 rising juniors, 1 rising senior, and 1 fifth-year senior, ranging in age from 19 – 26 years. Of the 7 new participants, 3 were male and 4 were female.

**Participant First Day and Final Day Surveys and Focus Groups**

On the First Day, participants were asked "what do you plan to learn or be able to do as the result of the REU program," and a similar question that read "Specifically, what did you learn or now are able to do as the result of the REU program" was asked on the Final Day. Verbatim responses about learning outcomes expected at the outset of the program and those that were realized once the program was completed are shown in Table 2.

First Day predicted learning outcomes centered on the basics of conducting research and experiencing the laboratory techniques and environment. Final Day outcomes were quite different, in that they not only focused on learning the research process, but also on other learning such as exposure to scholarly journals, the lifestyles of graduate students and professors, how to write reports, and working independently.

**Participant Perceptions of Engineering Research**

Student perceptions of engineering research were measured by way of scaled agree/disagree questionnaire items, open-ended questions, and focus group discussion opportunities, including a collage exercise. One major theme of their responses is that participation in an REU program changed their pre-conceived notions of what working in engineering research is really like.

Three-word descriptions of "research in engineering" were collected from participants on the First Day and Final Day. These are included in Table 3. First Day student descriptors tended to

focus more on the anticipation of involvement in challenging work that could lead to inventions and innovations. Final Day comments were more likely to focus on the tedious nature of the work, the sometimes unknown results, and the importance of organization and patience.

What some participants perceived as a lack of closure in engineering research was a theme that emerged in focus group discussions, as well as the completion of collage exercises, which asked participants to choose cut-out magazine images and words to describe their experiences.

Table 2: REU Student Predictions and Assessments of Learning Outcomes

| | **Responses** |
|---|---|
| **Student Predictions from First Day**<br>Specifically, what do you plan to learn or be able to do as the result of the REU program at SMU? Please complete the following sentence:<br>"As the result of participating in REU, I will (be able to, learn, understand, etc.)……." | •be able to independently conduct research and present my findings to a group of professors. I will also gain experience in a laboratory setting<br>•learn how to research<br>•learn how to research<br>•I will be able to understand the research process<br>•be able to determine what area of mechanical engineering I want to pursue<br>•the process of beginning research and learning general techniques that will benefit my future<br>•learn the fundamentals of research in mechanical engineering |
| **Student Assessments from Final Day**<br>Specifically, what did you learn or are now able to do as the result of the REU program at SMU? Please complete the following sentence:<br>"As the result of participating in REU, I (am able to, learned, understand, etc.)……." | •learned about scholarly journals and how to use the databases to search them<br>•understand the research process: what to ask, how to go about setting up research, the thought process (to a certain extent)<br>•learned what doing research is like and learned about the lifestyles of grad students and professors<br>•am able to work independently to carry out research. I also can perform uncertainty analysis and write up reports<br>•I learned that organization is very important to conduct research<br>•understand the type of work involved in research<br>•I understand how research at universities works and the effort that goes into it |

Table 3: Student Descriptions of Engineering Research Before and After Participation in an REU Program

| **Three Words That Describe Engineering Research – First Day** | **Three Words That Describe Engineering Research – Final Day** |
|---|---|
| •focused, pragmatic, exciting<br>•learning, activities, expectation<br>•cutting-edge, new, challenging<br>•precise, patience, inventions<br>•exciting, challenging<br>•challenging, relaxed, endless<br>•innovative, technical, fresh | •novel, exciting, applicable<br>•reading, organized, innovative<br>•creative, tedious, helpful<br>•seeking, thought, patience<br>•organization, patience, expectation<br>•tedious, unknown<br>•slow, useful, work |

## Directional Statements

Several directional items on First and Final Day questionnaires addressed engineering research (see Table 4) and after-graduation plans. Final Day results were more positive in terms of students' belief that they were more knowledgeable about engineering research and the role of engineering research in society. Participants were also more positive in terms of their knowledge of the relationship between engineering measurement and engineering design and theory, as well as experience working with specialized engineering equipment. At the outset of the REU program, all seven participants agreed that they were interested in attending graduate school in engineering. On the final day, six still were in agreement, and one checked the "neutral" option.

Table 4: Student Attitudes Before and After REU Participation*

| | **Before** # agree (7 responses)** | **After # agree (7 responses)** |
|---|---|---|
| I am confident that I will be able to obtain the job I want after graduating from college. | 7 | 5 |
| I am interested in attending graduate school in engineering. | 7 | 6 |
| I feel that the Engineering curriculum at my current university contains sufficient 'hands-on' experience. | 2 | 3 |
| I feel I am knowledgeable about engineering research. | 2 | 6 |
| I feel I am knowledgeable about the role of engineering research in society. | 2 | 5 |
| I feel I have adequate experience in working with teams on engineering projects. | 6 | 3 |
| I feel I have adequate experience in working with specialized engineering equipment. | 1 | 4 |
| I feel I have adequate knowledge of engineering theory. | 4 | 3 |
| I feel I have adequate experience with the proper methods of making engineering measurements | 5 | 5 |
| I feel I understand the relationship between engineering measurement and engineering design and theory. | 0 | 3 |
| I feel that as the result of the REU program, I now have considerable 'hands-on' experience in engineering.*** | _ _ | 6 |

*A five-point scale from Strongly Agree (5) to Strongly Disagree (1) was used. This table reflects the number who checked a 5 or 4.

**Questionnaires for the "Before" measurement were completed on the afternoon of the First Day on campus, following an orientation session. "After" questionnaires were completed on the Final Day, after all REU activities were completed.

***Item asked on Final Day questionnaire only.

## Evaluation of the REU Program

At the REU site under study, a seminar on engineering graduate study was added as the result of recommendations by participants in Year 1. This seminar was well received by participants, who commented that it helped them consider what types of graduate programs they might consider. It also introduced or reinforced an interest by some students in pursuing doctoral work and becoming a university professor.

When asked how the REU program might be improved, suggestions included more structure and goal-setting for projects, and feedback from professors and graduate students. Participants acknowledged that, unlike normal classes they take during the semester, the nature of engineering research was sometimes uncertain. Many said it was frustrating that they could neither finish nor control the projects on which they were working. Again, the lack of closure that such an experience sometimes results in was cited as a disappointing but understandable aspect of the work.

**Discussion**

The purpose of this paper was to report on the second year of a three-year REU Site program at SMU. The paper discussed program recruiting methods, selection of applicants, feedback from program applicants, and pre- and post-program feedback from participants. Also discussed were changes implemented to the 2008 program based on evaluations performed on the 2007 program.

Changes to the 2008 program were successful based on feedback from participants. The emphasis on recruiting using contacts at other universities did not increase the number of applicants, but the PIs felt that the average quality of the applicant pool was higher. The graduate school seminar was very well received by students. The discussion of expectations and work schedule at the beginning of the program resulted in fewer questions from students about the daily work schedule.

Similar to the 2007 study[4], the REU experience did not necessarily increase participants' desire to attend graduate school. In 2007 the number of participants interested in attending engineering graduate school decreased from 8 to 5. However, in 2008 only one student reported a decreased interest in attending engineering graduate school. The difference between years 2007 and 2008 may be a result of a number of factors, including a change in type of students participating. The 2008 participants had not advanced as far in their engineering curriculum, with only 2 seniors in the program in 2008, compared with 5 seniors in 2007. Another contrast to the 2007 REU evaluation was that fewer participants in the 2008 program felt they gained an understanding of the relationship between engineering measurements and engineering theory. This again may be attributed to the fact that the 2008 program had fewer rising seniors compared with the 2007 program. It is likely that the rising seniors had a stronger theoretical basis and context for the relation between engineering measurements and theory.

As a result of the program, participants generally felt that they gained a stronger understanding of engineering research, the role of engineering research in society, and significant hands-on experience. In both years student perception of engineering research changed over the course of the program. At the beginning of the program student descriptions of research were related to the rewarding and challenging aspects of research. At the conclusion of the program more students responded with descriptions related to the time-consuming, tedious nature of research. Another issue that did not appear to change appreciably from 2007 was the lack of "closure" and structure in a research environment. The participants were sometimes frustrated by the fact that research goals were not reached during the period of the REU program. Thus they did not achieve the closure they might get from a typical classroom experience. Students also were frustrated by the lack of a more detailed structure for performing research and indicated they

would have liked more feedback on their performance in the program. One of the planned changes to the 2009 program will be to provide more preparation for the poster presentations and feedback to the students on their posters.

## Conclusions

The second year of a REU Site in mechanical engineering was implemented at Southern Methodist University. The program placed 10 undergraduate students in experimental research labs with faculty and graduate student mentors. Participants in the program took part in optional surveys and focus groups on the first and last days to evaluate the program. The REU program provided participants with a hands-on experience that allowed them to gain exposure to a real research environment. Students reported that they gained a strong understanding of engineering research, the relation between engineering measurements and theory, and the effort that is required for performing engineering research. The surveys and focus groups evaluated the influence of the REU program on student perceptions of research. Student feedback from the 2007 program was successful in improving the experience for students in the 2008 program. Student feedback from the 2008 program will be used to further improve the 2009 REU experience.

## Acknowledgement

This material is based upon work supported by the National Science Foundation under Grant No. 0649032.

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