The Influence of a Research Experiences for Undergraduates Program on Student Perceptions and Desire to Attend Graduate School

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Abstract

Undergraduate research opportunities are valued by university faculty and administrators in part because of the belief that they are useful for attracting students to graduate school. Other perceived benefits are that these programs improve students' engagement in their respective disciplines, enhance students' understanding of theory by application to practical problems, and improve students' oral and written communication skills. This study evaluates an eight-week Research Experiences for Undergraduates (REU) program in the Department of Mechanical Engineering at Southern Methodist University to determine how the program influenced participants' perceptions of engineering research and their desire to attend graduate school. The program occurred over three consecutive summers involving students who were selected from a nation-wide pool of applicants. Unlike most retrospective-only, quantitative studies of students who participate in undergraduate research, the current study reports results of before-program and after-program surveys and focus groups conducted on-site. The use of qualitative methods to probe for global and specific attitudes toward engineering research provided a diagnostic element to the analysis that complemented typical learning outcome results. Participants indicated many positive aspects of the REU experience, including an increased understanding of engineering research, how to deal with uncertainty and setbacks in the laboratory, and gaining hands-on laboratory experience. Students said the experience would help them make a more educated decision regarding the pursuit of graduate studies, but in contrast to other published studies it did not necessarily increase their desire to pursue a graduate engineering degree. Positive outcomes of the program appear to be linked to the age of participants, with more positive outcomes associated with more mature students. Implications for managers and facilitators of undergraduate research opportunities are discussed.

I. Introduction

The importance of an undergraduate research experience is widely accepted and many recent studies have begun to document the positive effects on participants. Both qualitative and quantitative studies are being reported, often through surveys of student participants and sometimes their faculty mentors. The positive effects are reported as increased student interest in graduate school, increased engagement in their undergraduate studies, an increase in understanding of their field of study, and an increase in practical skills, such as problem solving, communication and information synthesis. The literature discussed below provided useful background for the planning of the REU site program, as well as items for the evaluation instruments employed at the beginning and end of the program.

Influence of Undergraduate Research Experience on Students' Interest in Graduate Studies

Undergraduate research experiences often are viewed as methods to recruit students to graduate programs. Compton (1995) surveyed students entering engineering graduate programs at several large research universities, all of whom received their B.S. degrees at U.S. institutions. The survey found that of the 178 respondents, nearly 50 percent had previously participated in some form of research as undergraduates, and 80 percent of those students indicated that their research experience influenced their decision to pursue graduate school.

Kremer and Bringle (1990) surveyed 22 students who previously participated in intensive undergraduate research in psychology on perceptions of their research skills in several areas. A control group of students with similar qualifications who did not participate in the program were also surveyed. Students who participated in research reported greater improvement in most research skills and were more likely to pursue a research career than non-participants.

Morley et al. (1998) surveyed students who previously participated in an undergraduate research program in Electrical Engineering at Georgia Tech, which was designed to attract minorities to graduate school in engineering. Of the 36 respondents to a survey, 92 percent indicated they were currently enrolled in, had graduated from or were planning to enroll in, an engineering graduate program. The responses were significantly higher than those from a control group of minorities, for which only 69 percent indicated graduate school experience or plans.

Narayanan (1999) reported a qualitative study of participants in an electrical engineering undergraduate research experience. The work emphasized the role of the faculty mentor and recruiting students from one's own institution. About one-third of the undergraduate students from the author's research group later enrolled in graduate school at the same university.

Zydney et al. (2002a) surveyed engineering alumni from the University of Delaware and compared respondents who participated in undergraduate research to those who did not. Respondents who participated in undergraduate research included those who had done so through the university's formal undergraduate research program, as well as through programs not under the formal university structure. Those who participated in research were much more likely to have attended graduate school and indicated that the early research experience influenced their decision.

Lapatto (2004) surveyed 83 percent of 1,135 undergraduate students from 41 universities and colleges who participated in undergraduate research projects. More than 90 percent of the respondents reported that the experience maintained or increased students' interest in pursuing a graduate degree.

Influence of Undergraduate Research Experience on Students' Skills

Another benefit of undergraduate research experiences are gains in pro-

ficiency in various skill sets, increased engagement in their discipline, and direction in their career paths. Sabatini (1997) describes an approach for including undergraduate students in his research program with an emphasis on the importance of the faculty mentor. The author describes the benefits of undergraduate research as described by both current and former members of his research group. Benefits identified by participants included improved knowledge and application to specific situations, enhancement of problem solving skills, experience working in teams, helping decide career paths, and experience communicating results. Hakim (1998) surveyed students after their participation in an undergraduate research program. Students reported that they developed a sense of belonging and contribution to their discipline, that they gained an improved understanding of research literature, techniques and equipment of their discipline, and that they gained proficiency in important skills in their discipline. Russell (2007) also stressed the importance of faculty involvement, and reported that the most common suggestions by student participants to improve their research experience were that faculty guidance be increased or otherwise made more effective.

The participants in the program studied by Zydney et al. (2002a) reported improved speaking and personal skills and an improved understanding of the scientific literature. Faculty mentors in this program reported that students gained increased cognitive and personal skills, improved their understanding of scientific studies, increased their ability to synthesize information, and improved their problem solving skills (Zydney et al. 2002b).

Lopatto (2003) surveyed science and engineering faculty mentors to undergraduate researchers at three institutions. Faculty reported that students learned a topic in depth and gained applied knowledge of a real problem. Students also learned the appropriate techniques for their field and improved their independent thinking, communication skills and problem solving skills. Students reported increased cognitive and social skills, enhanced credentials, and clarification of career path.

Lopatto (2004; 2007) reported increases in research skills as a result of the research experience. The study also reported improved tolerance for obstacles and working independently. In the 2007 study, however, a small group of students who reported significantly lower educational and experiential gains as the result of their research opportunity said they had discontinued their plans for postgraduate science education.

Motivation

Previous efforts to evaluate undergraduate research programs have relied on evaluating students after the conclusion of the experience. In this work, we describe a summer undergraduate research experience in the Department of Mechanical Engineering at Southern Methodist University. Unlike previous studies, our work evaluated student participants at the *beginning* and *conclusion* of the research experience to measure the influence of the program on student perceptions and desire to attend graduate school. This approach provides a better understanding of the direct impact of the experience on students, rather than an evaluation based only on reflection. In addition, this study reports both quantitative and diagnostic qualitative measures of the impact of an undergraduate research experience, and in doing so, analyzes not only "what" changes occurred after students experienced the program, but also their motivations, or the "why" behind their evaluations.

II. Description of the REU Site Program

The research experience was funded by a three-year grant from the National Science Foundation (NSF) Research Experiences for Undergraduates (REU) Site Program, hosted at Southern Methodist University (SMU). The program was held for eight weeks during the summer months, with student recruiting conducted in the spring semester. Students were recruited from the host institution and other U.S. institutions. The program theme was "Experimental Methods in Mechanical Engineering," which was chosen because of the large number of faculty in the department who had research programs that were primarily experimental in nature. As a hands-on activity, experimental research is attractive since hands-on research is appealing to engineering students and can be a useful retention mechanism (Felder & Silverman, 1988; Freeman et al., 2000; Nagda et al., 1998).

The REU program was advertised through an email message that was distributed to undergraduate engineering students at the host institution, faculty contacts at other universities and the Women in Engineering Program Advocates Network (WEPAN) nationwide list-serve. The email message referred potential applicants to a website that was used as the central source of information for interested students. In addition to the promotional email, a link to the website was provided on a searchable NSF webpage in the final two years of the program that listed all active REU sites. The host institution's REU website provided details on program location, deadlines, program dates, stipend, housing accommodations, dining, research information, and application information. Research information included participating laboratories, faculty mentors and potential project descriptions. Application information included eligibility requirements, contact information, application materials and an optional applicant profile questionnaire. The required application materials were a standard application form, resumé, statement of purpose essay, transcript, two letters of recommendation[1], and a rank-order list of at least two research projects in which the student was interested. The application form required student contact information, college/university currently attended, academic major(s)/minor(s) and GPA.

The principal investigators (PIs) selected participants from the applicant pool based on qualifications, interest in research and preferred 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 PIs, sometimes in consultation with potential faculty mentors, based on project preferences indicated by the applicants.

The first day of the program began with an orientation session focused on the program overview, a schedule of activities, paperwork, a campus tour, and a discussion of student performance expectations[†]. The expectations discussion included an overview of the research environment, expected work hours, appropriate behavior in the research laboratory, and effective communication between participants and research mentors. After the first day of the program, students reported directly to their research mentors. Since students were dispersed among various research groups, the PIs organized group activities outside of the laboratory to facilitate the cohort experience. Cohort activities included living quarters in the same building, a social event on the Independence Day holiday, three trips to local engineering-related companies each summer, and a seminar series. The trips to local companies were designed to expose participants to mechanical engineers working in design, manufacturing and/or research. Examples of companies that were visited were Alcon Laboratories, Texas Instruments, Lockheed Martin and Raytheon.

The seminar series was the main cohort activity of the program and required students to meet with the PIs weekly, except for the first and final week of the program. The seminars were developed and presented by the PIs, and the titles and descriptions are provided in Table 1. Sessions emphasized aspects of experimental methods and were designed to provide skills that would benefit both their REU experience and their professional careers. The PIs also assigned

[1] Added in Years 2 and 3

† Student performance expectations discussion added in Years 2 and 3 based on feedback from Year 1 participants.

Seminar Title	Description
The Purpose of Measurements	Overview of the types of experiments and their purposes
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 a research advisor, and funding for graduate school

Table 1: REU Seminars on Experimental Methods in Mechanical Engineering

‡ Graduate School seminar was added in Year 2 based on feedback from Year 1 participants.

the participants three activities which connected their research activity with the seminars: an uncertainty analysis, a final report and a poster presentation competition. The uncertainty analysis and final report were added to the program in Year 2. The uncertainty analysis was assigned after the completion of the "Uncertainty in Experiments" seminar and required participants to perform an analysis related to their project. Although the students did not have much experience with their research projects at the time the exercise was assigned, the project required them to think independently and critically about their projects at an early stage in the program. This allowed the PIs to provide feedback before the students had collected much data and afforded significant time for students to implement feedback into their final reports and poster presentations. The final report required students to summarize their projects in a brief format using information provided in the "Written Presentation of Results" seminar.

Near the conclusion of the program, the participants competed in a poster presentation which allowed them to demonstrate their research progress, utilize the presentation and experimental skills they learned in the seminar series, and to learn about the projects performed by other students. The posters were judged by faculty and staff members who were not REU research mentors. Judging was based on formatting, abstract, motivation, diagram of experimental apparatus, results and data presentation, significance of results and conclusions, and oral communication style. In addition to the judges, the event was public, with email invitations sent to all faculty and staff members in the school of engineering.

III. Program Evaluation and Results

Method

As mentioned above, an application was required of each student who wished to be considered for participation. Applications could be downloaded, printed, filled out, and mailed or emailed. A total of 29 applications were received in the first year, 23 in the second year, and 79 in the third year.

Those students who participated were asked to take part in evaluation activities on Day 1 of the program and again on the Final Day of the program. Day 1 activities included a paper and pencil questionnaire that was filled out immediately prior to a 45-minute focus group discussion attended by all participants. In cases where a student was participating for the second year, he or she was exempt from the evaluation activities to minimize duplication of responses.

Questionnaire and focus group items were drawn from the research literature, as well as the PIs' goals for the REU program. The Day 1 questionnaire contained open-ended items regarding perceived challenges and benefits of the program, followed by a question asking students to list three words that described engineering and then engineering research. The questionnaire concluded with a series of directional statements with a five-point agree/disagree scale regarding career interests, attitudes toward engineering, engineering research and engineering theory, and hands-on research experience. The Final Day questionnaire contained primarily the same questions as the Day 1 questionnaire, but phrased in the past tense.

The Day 1 and Final Day focus group discussions were led by a trained moderator who followed a discussion guide that included items about how participants learned about REU programs, attitudes toward REU programs, questions or concerns they had before the program started, personal goals for the program, and an opportunity for a collage exercise whose focus was participants' attitude toward engineering research. Participants sat around a conference table for the discussion, which was audiotaped. Haskins and Kendrick (1992) note that the focus group is among the most widely used qualitative research methods, and emphasize the importance of a good moderator who can balance small-group dynamics and obtain input from all participants. The moderator for the REU evaluation had more than 20 years of focus group interviewing experience.

The collage technique, employed toward the end of the focus group session, is often used in marketing research to elicit emotions, attitudes and experiences about products, services and brands (Rickard, 1994; Costa et al., 2003). Its application for the current study was to compare attitudes about engineering research before and after the REU experience. For the collage, REU participants were given a blank sheet of paper and asked to select from among hundreds of words and/or images cut from magazines, and then paste the cut-outs onto the page. When everyone was finished, each participant held up the collage and explained to the group why they chose the images they did, and how the words and images related to their understanding of, and attitudes toward engineering research.

Participant Profile

The program provided support for nine students in the first year, 10 students in the second year, and 10 students in the third year, for a total of 29 students. However, three of the second year's participants had previously participated in the first year, thus only 26 individuals participated over the 3-year program. Of these participants, 18 were male and eight were female. The academic standing, based on the number of years in college, and the gender of the students each year of the program, are listed in Table 2. The academic standing of the students by actual earned credit hours is listed in Table 3, which differs slightly from the traditional standing based on number of years in college. Detailed discussions of each year of the program are provided in previous conference publications by the authors (Willis et al., 2008; 2009; 2010). Academic standing information in Tables 2 and 3 was determined by the PIs based on applicants' transcript and resumé information. The previous conference publications by the PIs reported the standings as indicated by the students on their applications. However, the standings reported by students were determined to be inconsistent, since some students reported credit-based standings while others reported the actual year in college.

Findings

	Year 1	Year 2	Year 3
Number of participants	9	7*	10
Male participants	7	3	8
Female	2	4	2
Rising sophomores	4	1	2
Rising juniors	2	4	3
Rising seniors (including 5th year seniors)	3	2	5

Table 2: Profile of the REU Participants

	Year 1	Year 2	Year 3
Rising sophomores	1	1	0
Rising juniors	5	1	4
Rising seniors (including 5th year seniors)	3	5	6

Table 3: Academic Standing of the REU Participants by Credit Hours

Participant First Day and Final Day Surveys and Focus Groups

Directional Statements

Student attitudes were evaluated before and after participation in the REU program with a series of questions with possible responses ranging from 1 to 5. A response of 1 indicated strongly disagree and a response of 5 indicated strongly agree. The questions and the total number of respondents indicating agree (4) or strongly agree (5) during all three years of the program are listed in Table 4. Changes were observed in responses to all of the questions when comparing before and after responses. Student attitudes on finding a desirable job after graduating (Q1) did not change significantly as a result of the program, although students were generally positive about finding acceptable employment.

When asked about their interests in attending graduate school (Q2), the responses were generally positive, however the number of positive responses declined slightly at the end of the program. This was mainly because of the

	Before** # Agree (26 responses)	After # Agree (25 responses)
1. I am confident that I will be able to obtain the job I want after graduating from college.	25	23
2. I am interested in attending graduate school in engineering.	23	19
3. I feel that the Engineering curriculum at my current university contains sufficient 'hands-on' experience.	14	10
4. I feel I am knowledgeable about *engineering research*.	5	22
5. I feel I am knowledgeable about the role of engineering research in society.	10	21
6. I feel I have adequate experience in working with teams on engineering projects.	16	13
7. I feel I have adequate experience in working with specialized engineering equipment.	4	15
8. I feel I have adequate knowledge of engineering theory.	13	16
9. I feel I have adequate experience with the proper methods of making engineering measurements	16	21
10. I feel I understand the relationship between engineering measurement and engineering design and theory.	10	18
11. I feel that as the result of the REU program, I now have considerable 'hands-on' experience in engineering.***	– –	21

Table 4: Student Attitudes Before and After REU Participation*

* 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.

§ A total of 10 students participated, but three had previously participated in Year 1 and were not included in the survey or focus groups to eliminate duplication and to minimize "expert respondent" bias in focus groups. The repeating participants included 2 males and 1 female.

responses from the first year, with eight students responding positively before the program and only five responding positively after the program. In the second year, the positive responses at the beginning and conclusion of the program were seven and six, respectively, while in the third year responses were unchanged before and after the program.

The program appeared to have a noticeable effect on students' understanding of engineering research (Q4) and the role of engineering research in society (Q5). Only a small number of students indicated an understanding of engineering research at the beginning of the program, (5) compared with 22 positive responses at the conclusion of the program. Similarly, students' understanding of the role of engineering research in society increased from 10 positive responses at the beginning of the program to 21 positive responses at the conclusion. Students also felt that they gained experience in working with specialized engineering equipment (Q7). In the first and second years, the increase in positive responses to question 7 were small, changing from two to three in the first year and one to four in the second year. However, in the third only one positive response was received at the beginning of the program, compared with eight positive responses at the conclusion of the program. Several students in the focus group discussions mentioned how confident they felt after the program in working with laboratory equipment, in many cases for the first time.

Similarly, questions 8, 9 and 10, which related to knowledge of engineering theory, experience with measurements, and understanding the relation between engineering measurements and theory received noticeable increases in positive responses as a result of the program. However, in the third year the results were more positive at the start of the program. For example, questions 8, 9 and 10 received seven, seven and eight positive responses at the beginning of the program in the third year, respectively. In the first year the positive responses to these questions were two, four and two, respectively. The difference could be explained by the academic standing of the participants. In the third year more than half of the participants were seniors, while in the first year nearly half of the participants were sophomores, based on the actual number of years in college. The advanced academic standing of the third year participants could have led to more confidence in their understanding of theory, measurements and the relation between theory and experiments.

Initially, only 14 students responded positively when asked if their university curriculum contains sufficient hands-on experiences (Q3). After completing the REU program, the number of positive responses declined to 10. The high level of hands-on experience afforded by the REU program may have prompted some students to realize their prior hands-on experience had not sufficiently prepared them for a research environment.

Students also responded less positively regarding their prior level of experiences working in teams on engineering projects (Q6). While teaming was not a goal of the REU program, some of the students did work closely with other

Three Words That Describe Engineering Research – First Day	Three Words That Describe Engineering Research – Final Day
Year 1 responses	
•consistent, hardworking, enjoy •innovative, astounding, necessary •eye-opening, valuable, interesting •time-consuming, interesting •cutting-edge, interesting, diverse •challenging, precise, rewarding •abstract, unclear, optimistic •challenging, investigative, detailed •exciting, rewarding, precise	•exciting, progressive, evolving •complex, intricate, demanding •understand, experiment, apply •very, very tedious •unknown, optimistic, meandering •interesting, unknown, ingenious •high-tech, tedious, broad •challenging, detail-oriented, repetitive
Year 2 responses	
•focused, pragmatic, exciting •learning, activities, expectation •cutting-edge, new, challenging •precise, patience, inventions •exciting, challenging •challenging, relaxed, endless •innovative, technical, fresh	•novel, exciting, applicable •reading, organized, innovative •creative, tedious, helpful •seeking, thought, patience •organization, patience, expectation •tedious, unknown •slow, useful, work
Year 3 responses	
•useful, exciting •forward-thinking, versatile, necessary •innovative, scientific, beneficial •ethics, creative, attentive •interesting, necessary, innovative •complex, unknown, cutting edge •helpful, experiments, measurements •testing, vague, unknown •innovative, creative, exciting •experimental, advanced, logistical	•slow, experimental, erratic •foundational, rewarding, technical •demanding, necessary, complex •forward-looking, broad, applications •focused, necessary, practical •tedious, unpredictable, revealing •relaxed, helpful, learning •failure, monotonous, exciting •innovative, creative, slow •experimental, specialized, comprehensive

Table 5: Student Descriptions of Engineering Research Before and After Participation in an REU Program

REU students and graduate students on their projects. The decline in positive responses may indicate that participants realized their previous teaming experience was not sufficient. Alternatively, the decline in positive responses may also reflect that their research experience lacked a team experience because they were given their own individual projects. In the focus groups, some participants described spending long hours in relative solitude in their respective laboratories if they were working on their own.

One question (Q11) that was posed only on the final day of the program asked if students felt they had considerable hands-on experience in engineering as a result of the REU participation. The response was very positive, with 21 students indicating overall satisfaction with the level of experience they received. It is possible that social desirability bias may have played a role whereby students, even though they were assured anonymity of their responses, may have felt compelled to answer in a way they believed would reflect positively on the REU program.

Participant Perceptions of Engineering Research

Student perceptions of engineering research were measured in three ways: 1) responses to the quantitative, directional item in Day 1 and Final Day questionnaires as described above, 2) a qualitative exercise in Day 1 and Final Day questionnaires that asked them to list three words to describe engineering research, and 3) a Day 1 and Final Day collage exercise that asked them to express their feelings about research via cut-out words and images. Verbatim student comments are listed in Table 5, with the results separated by year. Each row indicates the before- and after-program response of an individual student. In order to maintain confidentiality of students while tracking their responses, each student used a code name that was only revealed to the moderator.

On the first day of the program the four most commonly used words were challenging, exciting, interesting and innovative. Collage images and words echoed this feeling of anticipation. "Caffeine, long nights, and that Eureka moment," predicted one female participant. On the final day the theme of the descriptors changed to more closely reflect the realities of working in a research environment. The four most commonly used descriptors on the final day were tedious, applications/apply, experimental and slow. "Frazzled. . . frustrated. . . you don't always know the end result," said the same female participant at program's end. "Don't get frustrated even if you want to quit," said a male participant. Several participants selected photos of wrist watches to indicate the time and precision involved in conducting engineering research.

IV. Discussion

Previous research about undergraduate research programs has revealed that such opportunities are valued by faculty, administrators and student participants. The present study, conducted among a highly selective group of 26 participants in an NSF Research Experiences for Undergraduates Site Program, employed before- and after-program qualitative and quantitative measures to assess student attitudes and perceptions of engineering, engineering research and future career plans. The synthesis of quantitative data and qualitative results from the studies reported herein shed light on the changes detected pre- and post-program, as well as possible reasons behind those changes.

Overall, students who participated in the REU program demonstrated positive changes in levels of knowledge, as well as attitudes about the role and practice of engineering and engineering research. More than four times as many participants said they considered themselves knowledgeable about engineering research after finishing the program, and twice as many said they were knowledgeable about the role of engineering research in society. Three times as many said they felt they had adequate experience working with specialized equipment after the program than before, and almost twice as many said they understood the relationship between engineering measurement and engineering design and theory. After the program, 21 of 26 students said they felt they had "considerable hands-on experience in engineering."

Interestingly, although the vast majority of (23 of 26) students measured before the REU experience said they were interested in attending graduate school in engineering, after the program that number decreased by four, to 19 students. This finding runs counter to many previous studies that report undergraduate research experiences are contributing factors to interest in pursuing graduate engineering study (Morley et al., 1998; Zydney et al., 2002a). The results may have been influenced by the addition of the graduate school seminar in Years 2 and 3, but could have been influenced by the relatively young age of the Year 1 participants (which expressed the sharpest decline of interest in attending graduate school), in which more sophomores participated than any other year. Although most of the students were rising juniors by number of credit hours, many of them were only entering their second year of college.

Though the four students who had a change of heart about interest in graduate studies could be a normal fluctuation in attitudes, it is possible that the verbatim comments from the First Day and Final Day of the REU program may contain insights into their thinking. Challenging, exciting and innovative were typical First Day words used to describe engineering research, whereas Final Day words were more likely to include tedious and slow. Clearly, the incoming expectations of REU students about what engineering research would entail were modified by their two intensive months in the laboratory environment. Focus group discussions with the students further revealed that many of them said they wished there had been more of a sense of "closure" with their projects and that they found it challenging to assess the significance of their contribution to engineering research. In fact, the eight-week time frame did not allow many of them to see the end results of the overall research effort in which they were involved. Other comments mentioned the slow and technical nature of the work. One student commented that he had decided to go into industry after the REU experience because he wanted to see the results of his work in a more immediate fashion than he could realize in the laboratory.

These findings suggest that managing student expectations for research opportunities before, during and after their involvement in a research program could have an effect on their outlook as well as their self-reported outcomes. The three-word descriptions of engineering research captured before and after the program lends insight into aspects of the experience that were not addressed in the quantitative instrument used.

One reading of these findings could be that concentrated programs, such as REU, provide students with a true glimpse of the realities of graduate study and research, and therefore could serve as either a catalyst or a deterrent toward interest in graduate study, depending on the reaction of the individual student to those realities. The REU program in this study, unlike many undergraduate research opportunities that coincide with a normal academic term, during which students take other classes, is a full-time summer commitment, and therefore immerses the student in the experience. Focus group comments from participants indicated that the REU experience was very different from a normal semester in that their full attention was focused on a fairly tedious task. As many professors would attest, graduate study and the sustained pursuit of laboratory research is not appropriate for all students, and programs such as REU may in fact be effective in helping participants formulate career plans, though those plans may not result in enrollment in a graduate program. This observation is supported by the fact that most of the students who changed from a positive to a negative outlook toward attending graduate school were from Year 1, which had predominantly younger students (sophomores). Although Year 1 students were predominantly advanced by number of completed credit hours (Table 2), many were only rising sophomores. Years 2 and 3 had more mature students, with more academic experience and could reasonably be expected to have a more realistic expectation of the laboratory environment. Hence, any difficulties or lack of closure experienced during the REU program may not

have had as great an influence on their future educational goals.

It should be noted that several previous studies demonstrating positive outcomes were populated predominantly by juniors and seniors (Russell et al. 2007; Lopatto, 2007). Therefore, the reduced number of positive responses observed in the first year of this study may support the suggestion that third- and fourth-year students who self-select into research programs may have already determined their future plans, and the research experience simply confirms their decision (Lopatto, 2007). In year one of our study the younger students may not have formulated definitive career plans, therefore the experience may have changed their outlook. Russell et al. (2007) suggest that such programs be made available for first and second year students. However, considering that fewer positive outcomes were observed with younger students in the present study, extending the program to younger students should be done with caution and appropriate expectations.

One of the limitations of the study reported here involves the small and select nature of the population of students under study. Twenty-six students in a single university program focused on experimental engineering are not necessarily representative of other REU programs or other undergraduate research opportunities and programs. Despite this shortcoming, the pre/post-program evaluation with students affords a look at the knowledge and attitudinal shifts among participants, which were presumably affected by the REU experience. In addition, through pre/post verbatim descriptions of engineering research, the study offered insights into the matter of perception and reality among undergraduates who express an interest in engineering research as well as engineering graduate study.

Another limitation is that all data collected were self-reported by participating students. Future research might include a longitudinal study of participants to track their actual versus predicted career paths and views toward engineering research as well as feedback from student mentors on their observations of students' attitudes and perceptions during the program.

V. Conclusions

A three year REU Site in the Department of Mechanical Engineering at Southern Methodist University has been evaluated at the beginning and conclusion of each program year using student surveys and focus groups. The surveys and focus groups evaluated student attitudes and perceptions of engineering research. Results indicated many positive benefits of a REU program. While the program did not necessarily increase students' desire to attend graduate school, students reported an increased understanding of engineering research and its role in society. Students also reported an increase in their experience with proper measurement techniques and working with specialized equipment, and the relation between engineering theory and measurements. The large majority of participants reported that the program gave them significant hands-on experience in engineering.

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