AC 2009-1157: MEASURING THE IMPACT OF UNDERGRADUATE RESEARCH PROGRAMS ON ENGINEERING STUDENTS' ATTITUDES TOWARD GRADUATE STUDIES

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Measuring the Impact of Undergraduate Research Programs on Engineering Students' Attitudes toward Graduate Studies

Abstract

Attitudes toward graduate studies are an often overlooked, but potentially important factor in undergraduate engineering students' decisions of whether or not to pursue graduate studies in engineering. Graduate work, especially the Ph.D., requires extensive research, a skill not often emphasized in undergraduate engineering programs. A survey was developed to measure engineering students' attitudes toward graduate studies and examine the reasons students choose to not attend graduate school. The psychometric properties of the survey have been examined and are published elsewhere. The survey has been used to measure the effect(s) undergraduate research programs have on engineering students' attitudes toward graduate studies. Students who participated in the research programs showed increased attitudes from the beginning to the end of their programs and had significantly higher attitudes toward graduate studies than a group of students who did not participate in the programs. Research opportunities for undergraduates have expanded over the past several years with the initiation of federally funded programs such as Research Experiences for Undergraduates (REU) and the Ronald E. McNair Post-baccalaureate Achievement Program. During each of the last three years, New Jersey Institute of Technology has hosted two separate REUs as well as a McNair Program. Data across all three years have been combined to further examine changes in students' attitudes toward graduate studies after participating in one of the programs and to begin investigating possible differences between the students who attended the REU programs and the students who attended the McNair program. Students in the Ronald E. McNair Postbaccalaureate Achievement Program showed significantly higher attitudes toward graduate studies, were more positive about research and appeared more likely to pursue careers in academia.

Introduction

Factors that influence students' decision to attend college, how they choose which college to attend, and the career paths they choose are fairly well known. However, less is known about why students choose to enroll in graduate programs and the level of the degree they pursue. The issues appear to be more complex. For example, deciding to pursue a graduate degree is a major commitment of time and money. Pursuing an undergraduate degree is usually done within a relatively specific timeframe, whereas there are several unknowns in pursuit of a graduate degree, especially the Ph.D., to the point where it can almost be considered an "endurance contest." Graduate work, especially the Ph.D., requires intense work and research -- a much more demanding course load than a typical undergraduate program[1], or even a Masters program, which tends to deter many students.

Other factors that influence enrollments in graduate programs, particularly engineering programs include the lack of growth in undergraduate engineering enrollment and graduation rates that limit the pool of eligible applicants to graduate engineering programs[2]. Studies have been reported on retention and attrition of students in undergraduate programs[3]. Among the many factors related to why students decide to pursue (or not to pursue) careers in engineering is their lack of knowledge regarding engineers and what they actually do. One approach to

increasing students' knowledge of engineering has been to determine how the presence of engineering can be increased in K-12 schools[4, 5]. As a result, there has been a growing interest by higher education institutions to bring engineering and technology principles and applications to the secondary school classrooms.

One of the major concerns with this solution has been the perceived negative attitudes by K-12 populations towards engineering and their lack of knowledge about what engineers do. Thus greater attention has been given recently to studies of attitudes toward engineering and knowledge of engineering and engineering careers for high school students, middle school students, teachers and guidance counselors[6-10].

However, no recent studies have been found regarding factors that impact the decisions of undergraduate students to pursue or not pursue graduate studies, or their attitudes toward graduate studies although one study[11] did report on a survey of seniors in engineering. Seniors were asked whether or not they intended to pursue full-time graduate studies. Then those who said they were going to graduate school were asked why, and those who were not going were asked why not. The primary reason given for attending graduate school was to learn more about their major. Pursuing a career as an educator was of lesser importance. Primary reasons for not pursuing graduate studies were the desire to get some practical experience first, tired of going to school, and high starting salaries for B.S. degree engineers. The authors recommended providing opportunities for undergraduate engineering students to obtain research experiences.

Research opportunities for undergraduates have expanded over the past several years with the initiation of federally funded programs such as Research Experiences for Undergraduates (REU) and the Ronald E. McNair Postbaccalaureate Achievement Program. During each of the last three years, New Jersey Institute of Technology (NJIT) has hosted two separate REUs as well as a McNair Program. As part of the effort to evaluate the effectiveness of these programs, the Attitudes toward Graduate Studies Survey was developed to measure the impact of the research experience on students' attitudes towards pursuing graduate studies, especially a Ph.D.[12]. The survey uses attitudinal scales to measure undergraduate students' attitudes toward graduate studies, their engineering skills self-efficacy, and their level of school-related self-confidence.

Development of the Attitudes toward Graduate Studies Survey

The Attitudes toward Graduate Studies Survey was modeled after the Attitudes to Engineering Survey[6-10]. Several drafts of the survey were reviewed and revised based on feedback from engineering faculty and interviews with a group of students who took the survey. Students are asked to indicate the degree to which they agreed or disagreed with a total of 30 statements about careers in engineering, the benefits and or disadvantages of graduate studies, their desire to pursue graduate studies and the obstacles students face in pursuing advanced degrees. Agreement is measured on a five-point scale where 1 indicates strong disagreement and 5 indicates strong agreement. Most statements are phrased positively such that agreement is desirable, but some statements are phrased negatively and disagreement is desirable. For example, one item states "The research requirements necessary to complete a graduate degree are undesirable." To score the entire survey, responses to the negatively phrased items are reversed so that higher average scores reflect more positive attitudes toward graduate studies.

A pilot study was conducted to begin examining the psychometric properties of the survey and collect information about what undergraduate engineering students think of pursuing graduate studies[12]. Engineering students participating in REU programs at NJIT during the summer of 2006 completed the Attitudes to Graduate Studies at the beginning and end of the program to evaluate the impact of the research experience on their attitudes toward pursuing graduate studies, especially a Ph.D. The survey was also given to a small heterogeneous sample of other engineering students at NJIT during the 2006-2007 academic year. Although the psychometric properties were not as strong as desired for a valid and reliable instrument, they were very encouraging for a small sample. Students in the research programs were found to have significantly more positive attitudes toward graduate studies than a control group of other engineering students. Significant differences were also found between male and female students on issues of gender equity.

The survey was revised for use in 2007-2008. During the summer of 2007 the survey was given to students in REU programs at other universities in addition to the students in the REU and McNair programs at NJIT. During the 2007-2008 school year the survey was also given to a larger control group of other engineering students for comparison and to more adequately examine the psychometric properties of the survey. A summary of the psychometric properties for the revised survey and the results of the evaluation of the effects the various REU programs and the McNair program had on engineering students' attitudes toward graduate studies during the summer of 2007 are reported elsewhere[13].

The Revised Survey

In addition to providing an overall measure of students' attitudes toward graduate studies the survey provides subscale measures of 1) the benefits of graduate studies (e.g., The research requirements for a graduate degree would be beneficial for a career in engineering), 2) the negatives of graduate studies (e.g., The benefits of pursuing a graduate degree are not worth the effort), 3) students' engineering skills (e.g., I have good problem solving skills), 4) their personal goals and desire (e.g. If I were to complete a Ph.D. I would consider becoming a professor), 5) the obstacles in pursuing a graduate degree (e.g., The financial costs of attending graduate school may prevent me from pursuing an advanced degree), and 6) gender equity (e.g., To be successful, it is more important for women to attend graduate school than for men).

The Effects of Undergraduate Research Experiences on Students Attitudes to Graduate Studies

Summer programs such as REUs and the McNair program employ many strategies to prepare students for research and graduate studies. First and foremost, students work in research laboratories throughout the summer, interacting with faculty mentors and graduate students, learning hands-on how to do research. In addition, students receive help with resume writing, interview skills and graduate school applications. Students are required to prepare a technical report of their experience and conduct a poster presentation. The students in the 2007 summer programs were asked to complete the survey at the very beginning of their respective summer programs. To evaluate whether participation in the programs changed their attitudes toward graduate studies they were asked to complete the survey again at the end of their programs.

Although students' attitudes toward graduate studies became more positive, no significant differences were found between their overall scores, or any of the subscale scores, from the beginning to the end of the summer program, but the power of the statistical analysis was low due to the small sample size. Another group of 32 students who attended REUs and the McNair program during the summer of 2008 were also asked to complete the survey at the beginning and end of their programs. Data across all three years, from 2006 to 2008, have been combined to further examine changes in students' attitudes toward graduate studies after participating in one of the programs and to begin investigating possible differences between the students who attended the REU programs and the students who attended the McNair program.

Results

Ninety four undergraduate engineering students attending research programs at NJIT completed the Attitudes toward Graduate Studies survey during the summers of 2006, 2007 and 2008. Sixty-five percent (n=61) were male and 35% (n=33) were female, which reflects a slightly higher percentage of females than that in the scientific workforce[14]. See Table 1 for a summary of other demographic information, including the ethnic composition and distribution of majors.

Table 1
Summary of Students' Gender, Ethnicity, and Major

	N	%
Gender		
Male	61	65
Female	33	35
Year Completed		
Freshman	7	8
Sophomore	44	46
Junior	43	45
Ethnicity		
African American	12	13
Asian Pacific	10	11
Hispanic, Latino	27	29
South Asian	11	12
Caucasian	29	31
Bi-Racial	1	1
Other\Not specified	4	4
Engineering Major		
Electrical	9	9
Chemical	28	31
Computer	18	19
Computers & Math	6	6
Bio-Medical	17	18
Mechanical, Civil	12	13
Other	4	4

Two students who attended one of the REU programs during the summer of 2008 did not complete the survey at the end of the summer; therefore statistical analyses comparing students' responses before and after attending the program are based on a sample of 92.

Overall Attitudes to Graduate Studies Prior to Attending a Research Program

In general, most of the students (94%) agreed or strongly agreed they decided to study engineering because it would lead to an interesting career and 69% (67% of females and 71% of males) agreed they would like to continue their education by pursuing a graduate degree in the same area as their undergraduate major. Forty percent (31% of females and 45% of males) indicated they had decided to apply to a Ph.D. program and 23% indicated that they would like to complete a Masters degree but not a Ph.D. (24% of females and 22% of males). Only 4% agreed that the benefits of pursuing a graduate degree are not worth the effort, although another 10% neither agreed nor disagreed. Only 20% percent indicated they did not think that they had the endurance to attend school for at least another five year to complete a Ph.D. program. Less than 5% of the students indicated they felt the benefits of pursuing a graduate degree were not worth the effort and almost all the students (93%) agreed the research requirements for a graduate degree would be beneficial for a career in engineering. Based on these responses one would expect more engineering students to be enrolling in graduate engineering programs.

One possible explanation is that 60% of the students agreed that pursuing a graduate degree in a field different from your undergraduate major is a good way to expand your career options. Another possible reason there are not more students actually pursuing graduate degrees in engineering is that 23% agreed that people should work for a couple years in their field before pursuing graduate degrees. Perhaps these students either like their jobs or enjoy the high salaries enough that they never return to school because 51% agreed that they decided to study engineering because they thought they could make more money than in most other fields. Other possible explanations are that 38% indicated that finances might prevent them from pursuing an advanced degree and 15% indicated that their grades or GRE scores might be too low.

While 77% indicated they were confident in their ability to pursue graduate studies only 42% agreed that they will have the skills necessary to begin a Ph.D. program by the time they complete their undergraduate degree. One theory is that although students may feel confident in their own academic abilities they may not feel confident enough about their research skill to complete a Ph.D. program, making research programs necessary as they introduce students to research methodologies and provide them many of the necessary skills.

Overall Attitudes toward Graduate Studies scores were calculated for each of the 92 students who completed the survey at the beginning and end of their summer research program by calculating the mean response across all 29 statements on the survey after the negatively phrased items were reversed so that higher average scores indicate more positive attitudes. Although students' attitudes toward graduate studies became more positive, paired t-tests found no significant difference between their overall scores from the beginning (mean=3.6) to the end (mean=3.7) of the program or for any of the subscales but some interesting significant differences were found when the individual items were examined. Because comparing the beginning and ending scores for each item required 29 t-tests Bonferroni's correction was

applied and only differences significant at p<.0033 for an overall Type I error rate of .1 were considered significant. Students' responses to the statement "By the time I complete my undergraduate degree program, I will have the skills necessary to complete a Ph.D. program" increased from an average of 3.3 at the beginning to 3.8 at the end of the program. Responses to the statement "I feel confident in my ability to pursue graduate studies in engineering" and "I have decided to apply to a Ph.D. program" increased from 3.3 to 3.6, and responses to "If I were to complete a Ph.D. I would become a professor" increased from 3.5 to 3.8.

Differences Between Students Attending the REU Programs and the McNair Program

There are some differences between the REU programs and the McNair program. The REU programs are 10-week summer programs, while the McNair program is a 10-week summer program in which students continue during the academic year. While the focus of all the programs is on the importance of research and providing students with practical experience the McNair program places more of an emphasis on the importance of graduate studies and encourages students to pursue careers in academia. Comparisons were made between students who attended the two REU programs and the McNair program to investigating possible differences in their attitudes toward graduate studies and determine if students in the McNair program maybe more likely to become professors.

Some interesting differences were found. Students in the McNair program had significantly higher overall attitudes to graduate studies which showed an increase from the beginning to the end of the program. The average over attitudes to graduate studies scores for students in the McNair program increased from 3.7 to 3.9 while the scores for students in the REU programs showed no change from 3.6. At the end of the summer students in the McNair program more strongly disagreed with that "The benefits of pursuing a graduate degree are not worth the effort" (mean=1.2 compared to 1.8 for the REU students) and "The research requirements necessary to complete a graduate degree are undesirable" (mean=1.8 compared to 2.3 for the REU students). Students in the McNair program also more strongly agreed they had "decided to apply to a Ph.D. program" (mean=4.0 compared to 3.2 for the REU students) and that "The research requirements for a graduate degree would be beneficial for a career in engineering" (mean=4.4 compared to 4.2 for the REU students). The average response to "By the time I complete my undergraduate degree program, I'll have the skills necessary to begin a Ph.D. program" increased from 3.2 to 4.1 for students in the McNair program while the scores for students in the REU programs increased from 3.4 to only 3.6.

Conclusions

Students' Attitudes toward Graduate Studies is an often overlooked, but potentially important factor in undergraduate engineering students' decisions of whether or not to pursue graduate studies in engineering. The current paper described a survey developed to measure students' Attitudes toward Graduate Studies and the results of research to date on the effect(s) Undergraduate Research Programs have on students' attitudes toward graduate studies.

Overall, few significant changes were found in students' attitudes toward graduate studies from the beginning to the end of the summer research programs they attended. Although the students participating in the summer programs were interested in research and graduate studies, and

participating in these programs significantly increased their confidence that they will have the skills necessary to complete a Ph.D. program their overall attitudes toward graduate studies increased only slightly by the end of their research experiences. In hindsight the fact that these students had applied to and been accepted into an undergraduate research program based on academic performance might have been an indication that these students might already have more positive attitudes toward graduate studies with little room for improvement.

Students in the Ronald E. McNair Postbaccalaureate Achievement Program showed significantly higher attitudes toward graduate studies, were more positive about research and appeared more likely to pursue careers in academia as more of them agreed that they would become professors if they were to complete a Ph.D. program. Students in the McNair program more strongly agreed that they would be prepared for graduate studies when they completed their undergraduate degree and more strongly agreed that they intended to apply to a Ph.D. program than students in the REU programs. More work should be done to examine the differences between these programs to identify the factors responsible for the differences so that they may be incorporated into the REU programs.

The specific factors that lead students to become interested in research in the first place are not clear. Identifying these factors is an area of future research that may ultimately lead to improved strategies for involving undergraduate engineering students in research, thus increasing their interest in pursuing graduate studies in engineering disciplines. Currently work is being done to develop a version of the survey that can be sent to students who have completed their undergraduate degree in engineering to begin collecting information about what students actually do after completing their degree, how working or attending graduate school may affect students attitudes, and how their attitudes toward graduate studies may be different from students who have not yet graduated.

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