



The Impact of a Neuro-Engineering Research Experience for Undergraduates Site on Students' Attitudes toward and Pursuit of Graduate Studies

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Abstract

The benefits of undergraduate research programs have been well documented and are generally accepted within the engineering education community. Various survey instruments and metrics have been used to gauge the effectiveness of individual programs and undergraduate research programs in general. The current paper is a summary of an examination of the effectiveness of a three year NSF-funded Research Experience for Undergraduates site focusing on Neuro-engineering.

Since one of the goals of this REU site, and all undergraduate research programs at our University, is to encourage students to continue their education at the graduate level, the Attitudes Toward Graduate Studies Survey (AGSS) was developed to measure changes in students' opinions about graduate school and their plans to pursue or not pursue graduate studies as a result of participating in an undergraduate research program. The survey has been validated and used for several years, both at this university and several other universities. The survey is administered pre-post, at the beginning and end of each undergraduate research program.

Pre-post responses from students who participated in the Neuro-Engineering REU site over the last three years are compared to other measures, including program follow-up with students after their research experience and the nationally-available Undergraduate Research Student Self-Assessment (URSSA) survey, to identify areas of similarity and difference of results. A follow-up version of the AGSS survey was used with all students who participated over the last three years to gauge the longer term impacts of the program; for example, do students get a job in industry right away? Do they go straight to graduate school? Do they consider returning to graduate school if they work in industry? Additional post-graduation tracking is implemented to supplement the results of the follow-up survey.

Introduction

Since its inception, the National Science Foundation (NSF) has supported undergraduate research. Initially, support for undergraduates participating in research projects was provided as part of a research grant award. In 1959, NSF began offering the Undergraduate Research Participation Program, which provided summer support “for undergraduate students to work with faculty on *pecially designed research projects*.”¹ In some cases, support extended into the academic year. The program operated until 1981.

After a hiatus of several years, in 1987 the NSF instituted a new program, the Research Experience for Undergraduates (REU) program², with many of the same goals as the Undergraduate Research Participation Program. This program is cross-disciplinary, with all NSF

directorates supporting REU programs in their areas of concentration. The REU program has two primary components. (i) REU sites provide a summer research experience for undergraduate students, similar to the original Undergraduate Research Participation Program. (ii) The REU program also funds REU supplements, which provide additional funding to grants already awarded to add undergraduate researchers to the funded grant. This is similar to NSF's initial efforts to fund undergraduate research. Both components continue to the present time.

REU programs provide a number of benefits to multiple constituencies. The most obvious benefit is for the participating students. Students receive an authentic research experience, as well as stipends and support for room, board, and frequently for travel too. Faculty supervisors also benefit from undergraduate student participation in their research programs. The students perform research tasks which help advance the supervisor's overall research program. In addition, the program provides a valuable mentoring experience for both the faculty supervisor and graduate students in the supervisor's research lab. Since these graduate students are often doctoral students who may enter academia upon graduation, this mentoring experience is good training for a future career in the professoriate.

The nation clearly benefits from a more highly educated and qualified workforce, and undergraduate research programs have encouraged students to become more highly educated and qualified. REU programs have been found to improve students' research skills, as well as skills in teamwork and communications.³ Studies of REU sites have shown their positive impact on students' enrollment in graduate programs.⁴⁻⁷ Massi *et al.*⁸ found that students who participated in undergraduate research experiences, whether REUs or other programs, are three times as likely to expect to attend graduate school. Russell, Hancock, and McCullough⁹ found these students to be twice as likely to intend to earn a Ph.D. Whether undergraduate research experiences motivate students to pursue graduate studies, or dispel their fears about pursuing graduate studies, they clearly do have a positive impact on student enrollment in graduate programs.

According to the National Science Board¹, enrollment in engineering graduate programs has increased by over 45% from 2000 to 2011. Full time engineering graduate enrollment increased by a slightly higher percentage, over 48%, during this time period. Doctoral degrees earned in engineering fields increased by an even higher 57% during the same time period, and increased an additional 11% during the following two years¹⁰. Although we cannot definitely state that REU programs drove these increases, it is reasonable to conclude that the REU programs did play a contributory role.

There are relatively few studies that have examined the factors that lead students to pursue or not to pursue graduate studies. Those studies have identified the research requirement for advanced degrees, and the students' lack of research skills (or lack of confidence in their research skills), as a factor that dissuades students from pursuing graduate studies,¹¹⁻¹³ even though students mostly agree that the research component of graduate programs would be beneficial in their careers. Many students prefer to obtain practical experience in the workplace; after spending four or more years completing an undergraduate degree program, they simply are not ready to continue full-time studies. For the doctoral degree, the length of the program may also be a discouraging factor. Cost is also a concern for students, both the cost of the program and the

“opportunity” cost associated with wages not earned in the workplace while studying in a graduate program.

REU programs provide students with a genuine research experience and give them many of the research skills they will need to begin the research component of graduate programs. Programs typically include instruction in the use of research-specific laboratory equipment and general research skills, such as statistical analysis. The programs may also have formal and informal components that provide additional, useful training in areas such as presentation skills, technical writing skills, interviewing skills, and graduate application preparation. All of these skills are useful for participants, whether or not they intend to pursue graduate studies.

The current paper focuses on an REU site in neural engineering¹⁴ that ran at the New Jersey Institute of Technology (NJIT) during the summers of 2012, 2013, and 2014, with ten students participating each year. Each summer program ran for a total of ten weeks, during which students worked in biomedical research labs with faculty, post-doc, and graduate student mentors. Students worked in groups of two or three on topics in the following subfields: materials for neural tissue engineering; neurofunctional and neurobehavioral analysis; multicellular neural tissue engineering; and neuromuscular control. In addition to the laboratory research component, students participated in workshops on oral and written research communication, site visits to local industries, and a culminating research symposium at which they presented their research. By the end of the REU, students submitted their research abstracts—one per team—to the annual national conference of biomedical engineering (BMES)¹⁴.

Methods

Students who attended the Neural engineering REU during the summers from 2012 through 2014 were asked to complete the Attitudes Toward Graduate Studies Survey (AGSS)^{12,13,15} at the beginning and the end of their respective summer REU experience. Students indicated the degree to which they agreed or disagreed with a total of 29 statements about careers in engineering, the benefits and or disadvantages of pursuing a graduate degree, their desire to undertake graduate studies and the obstacles students face in pursuing advanced degrees. Agreement is measured on a five-point Likert scale where one (1) indicates strong disagreement and five (5) indicates strong agreement. Most of the statements on the AGSS are phrased positively so that agreement is desirable but some of the statements are phrased negatively and disagreement with these statements is actually positive. For example, the statement “The research requirements necessary to complete a graduate degree are undesirable” is phrased negatively so that disagreement becomes a positive response. For the overall scoring of the survey, responses to the negatively phrased statements are reversed so that higher average scores reflect more positive attitudes toward graduate studies.

The AGSS also includes several open-ended questions about students’ major, their GPA, how students chose their major, whether they have decided to pursue an advanced degree, how they came to their decision(s) if they decided to pursue another degree in a field other than their undergraduate major and other demographic information. See Table 1 for a summary.

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

Year	<u>2012</u>	<u>2013</u>	<u>2014</u>	<u>Total</u>
Gender				
Male	7	6	3	16
Female	3	4	7	14
Ethnicity				
African American	0	1	0	1
Asian Pacific	2	0	0	2
Hispanic, Latino	0	2	1	3
South Asian	1	1	1	3
Caucasian	6	5	8	19
Biracial	1	1	0	2
Engineering Major				
Bio-Medical	8	7	5	20
Mechanical	1	0	0	1
Electrical	1	2	1	4
General Engineering	0	0	1	1
Other Science	0	1	2	3
Undeclared	0	0	1	1

An alumni version of the AGSS was developed as a follow-up instrument for a previous study⁴. All 30 students who attended the REUs during 2012, 2013 or 2014 were asked to complete the alumni version electronically during the Fall of 2014. Responses were received from 27 of the 30 students. The alumni version presents students with the same 29 statements of the pre-post survey, which measure the participants' current attitudes and asks specific questions about if and when they finished their undergraduate degree and what, if any, graduate programs they may be or had been enrolled in.

At the end of each Neuro REU (2012, 2013, and 2014), participants were also asked to complete the Bio REU (IBS-SRP or Integrated Biological Sciences Summer Research Program) instrument for Undergraduate Research Student Self-Assessment (URSSA). In particular the Neuro REU used the 2010 IBS-SRP developed by Janet Branchaw, with the University of Wisconsin-Madison. As noted on the program's web site, this "is an online survey instrument for use in evaluating student outcomes of undergraduate research experiences in the sciences."¹⁶ The survey is administered by the Center for Ethnography and Evaluation Research at the University of Colorado at Boulder. Unlike the AGSS, which focuses on the attitudes of undergraduate research program participants toward graduate studies, the URSSA survey incorporates a focus on the mechanics and outcomes of the undergraduate research programs themselves.¹⁷ The AGSS and URSSA complement each other, giving an overall picture of how well the

undergraduate programs were run and how they influenced students' future participation in graduate programs.

The survey is hosted on the Student Assessment of Learning Gains¹⁸ platform. Users create an account on the server and then create their own instantiation of the URSSA instrument. Some of the questions on URSSA can be modified or deleted if desired. Although the two surveys—i.e., AGSS and URSSA—have different areas of focus, there are some areas of overlap that allow us to examine the results of the two surveys for consistency.

Results

Repeated measures analysis of variance was used to test for changes in students' attitudes toward graduate studies across the time periods from the beginning of their REU experience to the follow-up during the Fall of 2014. Students' attitudes were examined for all 27 students combined and then again for each of the three cohorts individually (2012, 2013 and 2014). No meaningfully significant changes were found in students' overall attitudes or in any of the six subscales. In retrospect, these results are not surprising. Students' overall responses were extremely positive even at the beginning of their respective REU experience leaving little room for positive changes. The fact that these students had applied and been accepted into a highly competitive research program such as this REU (about 400 applicants per year) is probably an indication that they are already somewhat positive about graduate studies, although not necessarily for a Ph.D. or medical school.

The responses students provided to the open-ended questions related to their desire to pursue graduate studies after completing their summer REU experience were compared to results from the alumni version used as a follow-up in the Fall of 2014. Many students were unsure about whether they would pursue graduate studies and others were undecided between pursuing a masters or a Ph.D. degree when they completed their REU experience. In contrast, most students who had finished their undergraduate degree by the time they responded to the follow-up survey reported they were enrolled in an advanced degree program.

Of the 27 students who responded to the follow-up survey, eight had attended the REU during 2012, nine had attended during 2013, and ten had attended during 2014. Because students typically attend REU programs during the summer between their junior and senior years, the students who attended during the summer of 2014 would not yet have completed their undergraduate degrees. Of the eight who attended during 2012 two reported being enrolled in medical school, two in Ph.D. programs, two in masters programs, and one had applied to graduate school (degree program not specified) but had not yet been accepted. Only one of the students who responded from 2012 was not enrolled in/nor had applied for post-graduate studies. Although some of the students who responded from 2013 did not provide enough details about the graduate degree programs they were currently enrolled in to determine if the programs were masters or Ph.D. programs, seven out of the nine were enrolled in some type of a graduate-level program including medical school and Ph.D. programs. Table 2 shows the students' replies.

Table 2
Summary of Graduated Neuro REU Alumni Enrollment in Graduate Programs by Year and Gender

<u>Year attended</u>	<u>Gender</u>	<u>Degree Completed</u>	<u>Enrolled in</u>
<u>2012</u>	Female	BS Biomedical Engineering	Ph.D. Biomedical Engineering
	Male	BS Biomedical Engineering	Ph.D. (subject not specified)
	Male	BS Biomedical Engineering	Medical School
	Male	BA Neuroscience	Medical School
	Male	BS Biomedical Engineering	MS Biomedical Engineering
	Male	BS Biomedical Engineering	MBA
	Female	BS Biomedical Engineering	Applied but not yet accepted
	Male	BS Biomedical Engineering	None
<u>2013</u>	Male	BS Biomedical Engineering	Ph.D. Biomedical Engineering
	Male	BS Biomedical Engineering	Medical School
	Male	BS Biomedical Engineering	Neuroscience graduate program
	Female	BS Biomedical Engineering	MS Biomedical Engineering
	Female	BS Biomedical Engineering	MS Biomedical Engineering
	Female	BS Electrical Engineering	MS Astronautical
	Male	BS Astrophysics	IT graduate program
	Male	BS Electrical Engineering	None
	Female	BS Biomedical Engineering	None

Of the students who attended during the summer of 2014, only two indicated they disagreed with the statement “I have decided to apply to a Ph.D. program” on the follow-up AGSS. Seven indicated they were neutral (i.e., unsure) whereas one indicated agreement. Five of the seven who were neutral agreed they “would like to complete a masters degree but not a Ph.D.” The overall indication is that so far at least six of the ten students would like to pursue graduate studies at some level.

Many of the questions on the URSSA are related to skills students would need in order to be successful in graduate school; other questions specifically address whether students are more likely to pursue graduate studies after participating in the REU program. Table 3 provides a summary of the responses to the most relevant questions received from the 27 students who completed the URSSA (N=10 from 2012, 7 from 2013 and 10 from 2014). Questions are identified by their corresponding section and number from the URSSA (e.g., 2.1 indicates the first question in section 2 of URSSA).

Table 3.
Summary of REU participants' Responses to selected Items Related to Graduate Study Skills on the URSSA (expressed as a percent for N=27 who responded across 3 years)

How much did you GAIN in the following areas as a result of your research experience?	No gain	Little gain	Moderate gain	Good gain	Great gain
2.1 Confidence in my ability to contribute to science.		8 %	11 %	48 %	33 %
2.7 Understanding what everyday research work is like.		8 %	4 %	22 %	67 %
3.1 Writing scientific reports or papers.		11 %	26 %	26 %	37 %
3.2 Making oral presentations.	4 %	8 %	11 %	33 %	44 %
3.13 Managing my time.	4 %	15 %	22 %	56 %	4 %
During your research experience HOW MUCH did you:	None	A little	Some	Fair amount	Great deal
4.1 Engage in real-world science research			11%	37 %	52 %
4.6 Work extra hours because you were excited about the research.		11 %	15 %	30 %	44 %
Rate how much you agree with the following...	Strongly disagree	Disagree	Agree	Strongly agree	
7.1 Doing research confirmed my interest in my field of study.	4 %	4 %	70 %	22 %	
7.2 Doing research clarified for me the field of study I want to pursue.		4 %	74 %	22 %	
7.3 My research experience prepared me for advanced work\thesis work.		19 %	63 %	19 %	
7.4 My research experience has prepared me for graduate school.	4 %	11 %	60 %	26 %	
7.7 My research experience has clarified for me that I do not wish to pursue a career in scientific research.	41 %	26 %	26 %	8 %	
Compared to your intentions BEFORE doing research, HOW LIKELY ARE YOU NOW to:	Not more likely	a little more likely	Somewhat more likely	Much more likely	Extremely more likely
8.1 Enroll in a Ph.D. program in science, mathematics or engineering?	46 %	12 %	27 %	15 %	
8.2 Enroll in a Masters program in science, mathematics or engineering?	28 %	20 %	16 %	24 %	12 %
8.3 Enroll in a combined M.D./Ph.D. program?	41 %	22 %	22 %	8 %	8 %
8.4 Enroll in medical or dental school?	52 %	15 %	11 %	8 %	15 %
8.5 Enroll in a program to earn a different professional degree? (i.e. law, veterinary medicine, etc)	88 %	4 %	4 %	4 %	

Chi square tests of Independence were used to test for differences in the responses among the three different cohorts of students (2012, 2013 and 2014). No significant differences were found on any of the questions summarized in Table 3. Most students felt they gained a lot from the experience and that they were much more prepared to conduct research, particularly thesis work (see question 7.3). Fifty-four percent of the REU participants indicated that they were at least a little more likely (if not much more likely) to enroll in a Ph.D. program after their summer research experience and 72% indicated that they were at least a little more likely (if not much more likely) to enroll in a masters program. As no significant differences were found among the three cohorts of students, these results help further support the expectation that a majority of the students who participated during the summer of 2014 will pursue graduate studies.

Participants were asked an open-ended question “**How did your research experience influence your thinking about future career and graduate school plans? Please explain.**” Table 4 is a summary of their unedited responses by year attended. Clearly, most participants who provided a detailed response were influenced by their summer REU experience. Some responses were not as positive toward research and graduate studies as others but overall many of the participants appear to have made a decision to pursue graduates as a result of their participation in the REU.

Table 4.

**Summary of REU participants’ Responses to Question #9 on the URSSA
“How did your research experience influence your thinking about future career and graduate school plans? Please explain.”**

Responses from students who attended during 2012:

It swayed me away from full time career in research, made me realize there are other things I can pursue as well

This research program gave me a great deal of insight on what I will need to be doing in graduate school alongside my coursework. I now have a better idea of what will be going on when I begin my thesis project and will know what to expect when it comes to the research experience. There will be few differences between experiences but when things go wrong I will have already developed the skills to identify the problem and fix it.

I enjoyed working in the laboratory environment, but I now know that academia is probably not the route for me. Also, I want to go for a Masters because of the additional expertise and experience afforded.

It gave me a good idea of what to look for and what to expect when applying to graduate school and an idea of the sort of lifestyle that graduate students lead. It also gave me some deeper insight into my field of interest and the different sub-fields within it.

I want to be a Research Scientist in industry (R&D). My ultimate goals are to be the Head Research Scientist. Because of this, I wanted to do research to refine my researching skills.

I think my research helped me to narrow down my search now that I know a little more about what I like and don't like. Also, being exposed to what's out there will really help me to make a decision.

My research experience gave some real-world exposure to the nature of research and the slow pace that can be frustrating at times. It is always one challenge after another. Because I like to challenge myself and love the feeling of overcoming these challenges, I now seek to enroll in a graduate program that contains a sizable research component. I am extremely interested in an M.D./Ph.D track

A lot of what is used in the field that I would like to head in based upon advanced physics and probability theory, and I do not feel strong in these fields. I learned this through my research experience because I used what would be considered basic techniques in other researchers’ eyes, and I would like to understand fundamentally how to use more advanced mathematical and instrumentation procedures.

I still want to pursue biomedical engineering, but I do not want a Ph.D.

Responses from students who attended during 2013:

I feel that I would definitely enjoy research but I am still considering other options.

I already knew I wanted to pursue a PhD and work in academia. My mind did not change.

This research experience has made me realize that I want to go straight into industry and not go to get my Ph.D

This research has given me hands-on experience which will be useful during graduate school.

Table 4 (continued).

Responses from students who attended during 2014:

I got to experience what academia is like but I would also like to look into industry. I have not decided between the two which I like better but I will probably go to graduate school.

This research helped confirm my desire to attend grad school, but not to pursue a career in academic research

well it showed me that i do not want to do PhD and that med school is the right choice for me. I like research but design is much more exciting for me.

I am more likely to enroll in a graduate program because I understand what it is like to work in a lab to finish my own project with deadlines and other obstacles. I enjoyed the research experience and I can see myself working like this for longer

It showed me what BME is all about and clarified this potential interest.

Instead of just wanting to pursue an M.D, I am also considering getting a masters in Biomedical engineering as an option as this research experience made me realize how important biomedical engineering is.

I feel more confident about my ability to succeed and thrive in a graduate school setting. I have more to go off of when thinking about which program I am going to choose because I have more experimental experience in my field.

I know what field I am interested, I know that I do not want to pursue a PhD and would rather go to either med school, industry or get a masters.

It allowed me to see what doing research at a university was truly like. Although I enjoyed the research a lot, seeing the high stress of my colleagues is making me reconsider going the pure research route. I might pursue a M.D./Ph.D program now.

I decided I do not want to go into research as a career.

Discussion

The outcomes of the Neural engineering REU program have been encouraging. Of those students who have already completed their undergraduate programs, 88% applied to graduate programs, and 82% are currently pursuing graduate studies. Both are significantly higher percentages than for the general student population¹⁹, and both exceed values predicted for the participants in this program in a previous follow-up study⁴.

The students in the 2014 cohort had not yet completed their undergraduate programs at the time of this study, but we can attempt to predict their outcomes based on their responses to the Attitudes Toward Graduate Studies Survey as compared to those of the 2012 and 2013 student cohorts. No significant differences were found amongst the three cohorts in their responses to the AGSS, so it is reasonable to expect similar percentages of students to pursue graduate studies upon completion of their undergraduate degree programs. Based on these survey results, we would expect 80% or more of the students in the 2014 cohort to pursue graduate studies once they have completed their baccalaureate degrees.

The results from the URSSA survey are consistent with the outcomes from the follow-up AGSS. As shown in Table 3, 81% of participants reported a good or great gain in confidence in their ability to contribute to science. With 82% indicating similar gains in their preparation to perform thesis work and 86% showing good or great gains in the preparation for graduate school, the program's goal to prepare and encourage students to pursue graduate studies clearly has been met. Almost all students agreed or strongly agreed that participating in the program confirmed

their interest in their field of study (92%) and clarified their interest in the field they want to pursue (96%). In short, the program solidified their interest in pursuing graduate studies and helped prepare them to succeed in graduate programs.

Interestingly, participants do not show gains that are quite as strong when examining their interest in entering doctoral or professional programs. Note that the URSSA survey measures the difference between their interest before and after participating in the program, not their interest. One reasonable conclusion is that the students most likely to pursue graduate studies are also the students most likely to participate in REU programs, so it is probable that these students already had a strong interest in pursuing graduate studies before entering the program. Thus their interest could remain high while still showing little or no change from the beginning to end of the REU program. Given the large percentage of students ultimately enrolling in graduate programs, it is likely that the replies to this question suffered from a ceiling effect, with most participants already interested in pursuing graduate studies before entering the program.

The open-ended comments provided by participants further confirms the positive impacts of this Neural Engineering REU program. As shown in Table 4, many of the participants found their interest in graduate programs and research were confirmed by participating in this program. For some students who were undecided between pursuing a medical degree and a PhD, the program helped them determine how they wanted to proceed. For a few of the participants, however, participating in the program led them to conclude that they did not wish to pursue a doctorate. By helping students make an informed choice about what is best for each of them, this can be considered a positive outcome as well. Certainly it would be better for these students to pursue what interests them most, rather than spend several years in a graduate program that does not match their goals and career desires.

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