

NC State Undergraduate Research for Composites in Extreme Environments, Second Year Study

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Abstract

Eight students participated in a NSF-funded Research Experiences for Undergraduates Site program focused on composites in extreme environments at NC State University during the summer of 2017. Students were polled at the beginning and end of their time to ascertain whether their feelings about research had changed during the research experience. Students were also interviewed in person. While students reported having a fantastic summer, survey questions were sometimes ranked less favorably at the end of the summer than at the beginning. Students reported being interested in graduate school at the beginning of the summer but their professed interest in going to graduate school declined from the beginning of the summer to the end of the summer for three of the eight students.

Keywords

undergraduate research, career path, graduate school, NSF, REU

Background

A generation ago in 1998, five different directorates at the National Science Foundation (NSF) gathered luminaries in fields from engineering to geosciences to discuss undergraduate education.¹ The need for undergraduate research opportunities was stressed in the biology workshop, the chemistry workshop, and the geosciences workshop and taken as a call to action in the executive summary. While undergraduate research was being discussed in engineering as well, it is curious that the seventeen luminaries in the engineering workshop did not discuss undergraduate research at that time; they were more concerned with the rapid pace of technological change and the decrease in engineering enrollment.² The press for undergraduate research has only grown since the '90s, and much credit goes to the National Science Foundation (NSF) who has funded teams all over the country including this opportunity.

The literature cites many benefits for students including subject matter expertise, familiarity with research techniques, improvement in teamwork and problem-solving, increased participation in graduate school, clarity in career goals, and the ability to analyze research literature.^{3,4} Faculty believe their participation in undergraduate research allows them to connect with individual students influencing their career choices as well as enhancing the research of the faculty members.^{5,6} Undergraduate research experience is often said to increase the likelihood for students to pursue graduate school.^{7,8,9}

Description of Program

Our program mirrored many of the ideas suggested for how to run a good undergraduate research program.¹⁰ Students applied online from all over the country. The students were evaluated on their credentials and their research interests. Eight students came to campus for nine weeks during the summer. Our students were principally from the east half of the country with students coming from Kansas, Illinois, Maryland (2), South Carolina, Georgia, New Jersey, and Texas. The students were diverse in gender and race: six male and two female, five white non-Hispanic, one Hispanic, and three Asian. Students, rising juniors and seniors, were housed in a dorm on campus and provided with a meal plan.

Students worked with their mentors in the lab for most of the time. Students were gathered back together for small-group meetings on specific topics such as career goals, literature reviews, and making good graphics. Students wrote and edited a research proposal and an abstract. They also prepared a poster and presented it at the NC State Undergraduate Symposium at the end of the program. Two field trips during the summer allowed students to tour a small composites company with <100 employees as well as a large government facility with 3,800 civilian, military, and contractor personnel to give students an industry perspective.

Students in the program studied individually with faculty mentors on the following topics:

- Using infrared thermography instead of ultrasound for nondestructive testing of carbon fiber-reinforced, polymer/foam composites to reduce false positives of manufacturing defects
- Fabricating low-density ceramic composite foams using a powderless infiltration (polysilazane precursor dissolved in hexane) to minimize nonuniform material shrinkage
- Measuring the bullet-impact response in aramid fiber composites (such as Kevlar) using a novel fiber Bragg grating with a silicone sensing layer
- Measuring radar permittivity for bismaleimide composites with and without moisture contamination after simulated hail strikes
- Lining helmets with carbon-nanotube-reinforced polyurethane films to dissipate impact energy
- Building artificial muscles with a silicone in a carbon-fiber matrix to eliminate the hydraulic or pneumatic internal bladder currently in use
- Designing a mechanism to unroll the boom for a solar sail for a CubeSat satellite.
- Computer modeling of iridium tin oxide materials with a Voronoi algorithm instead of triangles; matching the nanostructure of the material with curved tessellations in the hope of improving the match between stress/strain modeling results and experimental results

The students were surveyed initially at our first meeting when enthusiasm was high. The final surveys were handed out at the end of the symposium where students presented their posters. The students were also interviewed individually at the end of the program.

Results

In the exit interviews, seven of the eight students reported having a great summer where the REU had met or exceeded their expectations. The eighth student had had difficulties with equipment failures and with mentorship due to travel schedules. All the students reported having the information and the resources they needed to complete what they needed to do. Selected student comments:

It was kind of above my expectations really. I came in not really knowing if I wanted to do grad school. This was my first research experience. Before this grad school was an option but after this it's the plan. I really like the research. Learned a lot.

Whenever I had a problem, they were there to ask. It was definitely challenging I had to do a lot of independent thinking.

My grad student would let me spend days in front of a computer doing many things that wouldn't work before he would tell me how to do it.

I especially liked time management the best. The career service packet & the steps to do each year, that was really helpful. I really enjoyed the meetings.

Overall program evaluations were also good. Table 1 shows the student feedback on the program as a whole. The questions asked the students to rank how much they agreed with the statement on a 5-point Likert scale with 5 being strongly agree.

Table 1: Program Evaluation

The program:	Average
... was challenging and fun.	3.9
... provided me with good faculty mentorship.	4.4
... helped me better understand how to do research.	4.4
... encouraged me to pursue my own interests.	4.0
... provided opportunities to socialize with students like myself.	4.8
... provided opportunities to socialize with other faculty members.	3.9
... provided me with and adequate orientation to my project.	3.8
... provided a good match between my skills and interests and my project.	3.9
... provided campus housing that met my needs.	4.8
... communicated clearly what was expected of me.	4.6

REU programs have promise in two large areas: increasing student confidence and in encouraging students to continue to graduate school to continue in research. These two areas were surveyed at the beginning and at the end using slightly altered versions of the surveys found in the literature.¹¹

2018 ASEE Southeastern Section Conference

The first large set of questions tested confidence in research abilities from literature review to working with others. Results are shown in Table 2. Results are shown in average and with the number of students out of 8 who increased or decreased their evaluation before and after the program.

Table 2: Before and After Survey Results for Student Confidence.

	Average Before	Average After	Net	N >0	N <0
I am confident in my knowledge of research methods.	3.1	4.3	+1.1	5	--
I am confident in my ability to develop research questions which are interesting and researchable.	3.3	4.3	+1.0	5	1
I am confident in my ability to find research articles.	2.9	4.6	+1.8	7	--
I am confident in my ability to conduct a literature review.	2.5	3.5	+1.0	4	2
I am confident in my ability to discuss research findings.	3.5	4.8	+1.3	7	--
I am confident in my ability to work collaboratively with others.	4.6	4.9	+0.3	2	--
I am confident in my ability to work independently.	4.5	4.5	--	1	1
I am confident in my ability to evaluate the quality of a research study.	3.0	3.6	+0.6	5	1
I am confident in my ability to write up research for publication in a scientific journal.	2.75	3.9	+0.1	3	2
I think research is enjoyable.	4.0	4.0	--	3	1
I am confident in my understanding of ethics in science.	4.5	4.4	-0.1	2	3
I am confident in my ability to prepare an application to graduate school.	3.3	4.1	+0.9	4	1
I am confident in my ability to succeed in graduate school should I decide to attend.	3.9	4.8	+0.9	3	--
I have some experience in research project management.	3.6	3.5	-0.1	3	3
I am confident in my ability to write a technical report.	3.6	4.0	+0.4	2	--
I am confident in my ability to give a technical poster presentation.	3.1	4.8	+1.6	7	--

The averages for the pre- and post-surveys match the expectations set by the REU literature. Students felt more confident in their ability to find and discuss research articles. Especially notable is the ability to find research articles and discuss research findings where seven of the eight students increased their agreement with those statements. In our program the poster presentation was emphasized; it was encouraging to see that the student confidence increased in their abilities to present a technical poster.

The two subjects that showed a decrease in student confidence were in the understanding of ethics and their experience in research project management. These decreases were from a 4.5 out of 5 average to a 4.4 out of 5 for ethics and from a 3.6 to a 3.5 average for project management. These drops were attributed primarily to student fatigue and randomness in student survey responses. In both cases about the same number went up as went down. Not all the mentors in this project worked with the students to prepare a journal paper for their research which accounts for the two students who said that their confidence there did not increase.

Table 3 shows the before and after results from the surveys asking the students what they would like to do in the future. Note that some of these statements are ones where we would prefer the students did not agree; these statements are marked with an asterisk. The same 5-point Likert scale is used as above.

Table 3: Career Influence

	Average Before	Average After	Net	N >0	N <0
I place a high value on the role of research in my future career.	4.1	3.8	-0.4	0	3
I would be interested in enrolling in more courses related to research.	4.1	4.3	+0.1	3	2
Participating in research during graduate school is not a major priority for me.*	2.0*	2.3*	+0.3*	4*	2*
Developing research skills is an important part of my career goals.	4.4	4.1	-0.3	0	2
I would enjoy a research oriented job.	4.3	4.3	--	1	1
I would be interested in doing research in a university setting.	3.9	3.4	-0.5	2	4
I would be interested in doing research in an industrial setting.	4.5	4.3	-0.3	1	3
I would like to obtain a Masters degree in a science field.	4.4	4.0	-0.4	1	4
I would like to obtain a PhD in a science field.	4.4	4.3	-0.1	1	2
I would like a graduate degree not related to science (MBA, Law school, etc.).*	2.5*	2.3*	-0.3*	1*	4*

I am not interested in graduate school.*	1.3*	1.6*	+0.4*	3*	1*
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*The rows with asterisks in this table show statements where we would prefer that the students had answered in the negative.

The most crucial opinion for us would be those students who say that they are not interested in graduate school. At the beginning of the summer, six of the eight students gave this a 1 indicating that they are very interested in graduate school; the other two marked 2. It is difficult to show improvement in the numbers of students who are interested in graduate school when your cohort is made up of those who are already interested.

For four of the students, the chances they'd go on to graduate school in something unrelated to science decreased (as we would like it to). Only one student indicated an increase in the likelihood that they would pursue a graduate degree not related to science.

The interest in doing research in a university setting decreased for half the students with the interest in doing research in an industry setting also decreasing for 3 of the 8 students. However, in comparing student answers one by one, there was only one of the 16 answers here which changed by more than 1 point which leads us to conclude that there was not much change in the student opinion about doing research in their career.

Discussion

There is always randomness when humans fill out a survey with a Likert scale. Do I sort of agree or really agree? Strongly? These gradations are not always easy to parse. Little emphasis can be placed on such small differences among a group of eight students. These surveys and the conversations around them suggest that fatigue was an issue at the end of the summer. Future research should include surveys of the students after some time has passed to capture their views on the REU from farther out.¹²

The general impact of the REU at NC State was positive for the students. For the most part students felt like they learned a lot and would continue in the path towards graduate school which most of them had already planned on pursuing.

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