



Research Experiences for Undergraduates in Mechatronics, Robotics, and Automated System Design

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Abstract

Industrial automation makes modern manufacturing possible, and mechatronics and robotics are the building blocks for industrial automation. Even in challenging economic times, U.S. manufacturers are still looking to hire highly skilled workers in industrial automation and control. In addition, it is necessary to invest in research to help maintain America's leadership in these areas. This paper describes a summer program designed to provide a research environment for undergraduate students to learn about mechatronics, robotics, and automated system design. The goal is to help participants to understand the research process, to acquire laboratory skills, to expand their perspectives on science and engineering research, and to have a lasting influence on their career paths. Participants spent 10 weeks working on a research project with a mentor and a graduate student. Survey data suggests that students learned from the research experience and will build on the experience in pursuing future research careers.

Background

National surveys in 2011 and 2012 showed a continuous decline in the number of U.S. students who move on to attend graduate school [1]. In addition, there is a shortage of highly educated skilled workers in the manufacturing sector [2]. With increased pressure for accountability in undergraduate education from stakeholders such as parents and state legislators, higher education institutions are investigating avenues to improve the quality of education. Prior studies by Brownell and Swaner [3], Crowe and Brakke [4], Laursen [5], Lopatto [6], Taraban and Blanton [7], Russell et al [8], and Zydney et al [9] suggest that undergraduate research holds some of the answers to increasing student learning, retention, graduation rates and entrance into graduate programs. As a result, institutions across the country, as well as government agencies such as the National Institute of Standards and Technology (NIST), are providing more research experience opportunities for undergraduate students [10]. The National Science Foundation (NSF) has a program called Research Experience for Undergraduate (REU) that provides funding for universities to host a REU sites for 10 to 12 students per summer. The program also provides funding to supplement ongoing funded projects; the supplement can support one to two undergraduate students to work on research projects during the summer. Participants receive meals and lodging and a stipend (usually about \$600/week).

Brownell and Swaner [3] suggest the following strategies for implementing high-impact practices such as research experiences.

- Encourage faculty to provide mentoring, rather than just program oversight, and attend to the quality of the mentoring relationship (balancing challenge with support).
- Provide opportunities for “real-life” applications, whether through publication, presentations, or project implementation.
- Offer intentionally designed curricula that enhance students' research skills and build those skills over time, including prior to intensive undergraduate research experiences.

This paper describes an NSF funded REU site focusing on mechatronics, robotics, and automated system design and presents survey results and lessons learned from the first year of hosting the program.

Student Recruitment and Selection

The program targeted students who 1) have limited opportunities to participate in research on their home campuses; or 2) belong to groups that are traditionally underrepresented in engineering and science, including women, underrepresented minorities, and persons with disabilities. A flyer was designed and e-mailed to department heads at approximately 100 institutions, followed by a telephone call to ensure the message had been conveyed successfully and the flyer posted appropriately. The flyer included information about program's focus, duration, stipend, eligibility, deadline, and a link to an online application form. Campus visits were also conducted to meet with faculty and students in classes and at student professional organization meetings. Our hope was that faculty at these campuses would not only recommend students for our summer program, but also continue to advise these students on their home campuses after the program was over.

A web page was created to allow applicants to see the research projects, mentors, and activities. The application package needed to include (1) a personal information data sheet, (2) an official transcript, and (3) a recommendation letter. The personal data sheet allowed the project director to group applicants based on their research interests. The PI then worked with each individual mentor to select participants.

General Program Information

As described earlier, the program's goals included: (1) educate students about how research works; (2) provide a research community for students to engage in active learning. To achieve these goals, the following activities were provided:

Presentations on research methods and related projects

To learn about research methods, students had to opportunity to attend presentations on topics such as how to write an abstract, how to do a literature review, how to set up a working hypothesis, and how to conduct statistical testing. Students also attended presentations on imaging technologies, such as bipedal robot walking, robot herds, and microdevice design. The presentations were given by the mentors and other faculty members.

Individualized research experience

Each participant worked on a research project or area of his or her interest on a team with a designated faculty mentor and Ph.D. student. This was achieved through a multiple step selection process. First, the program matched students to projects based on student interest as indicated in the application package. Second, the mentor talked to students to verify their interest and background. Third, the students were notified about their project and mentor. To ensure each student would receive sufficient attention, each mentor supervised up to two participants per summer and each student worked on a team with a mentor and graduate student.

In addition, the project scope and depth were adjusted by the mentor based on student performance. Research projects included:

- Miniaturized automated color sorting system using programmable logic controller and web-based server
- Automated Detection of Occult Fecal Blood: Chemiluminescent Substrate Analysis and System Design
- Extracting Material Properties of Thin Sheet Metals via Spherical Indentation Data
- Fabrication of Brushless Ironless DC motor using Halbach Array
- Processing Power for a Prosthesis
- Building a Public Data Set for Vision-Based Simultaneous Localization and Mapping for Indoor Mobile Robots
- Development of a Foot Prosthesis that Relays Reaction Force Information
- User Modulated Function Generator for Projecting a Pattern via a Biaxial Wide-field Fast-scanning Mirror
- Design, Build, and Remote Control of a Miniature Automated Robotic Sorting System
- Wireless Recharge Station for Autonomous Quad-copters

The program had a very strong interdisciplinary flavor which allowed participants to learn from one another.

Learning Community

Several actions were taken to facilitate the formation of a learning community. First, all REU students were housed in the same dormitory, including students from other REU programs. Therefore, they can interact and learn from each other; since they are most likely in different projects and from different projects. Most importantly, they all have the same goal: to learn how to do research. Second, at “brown-bag” lunch meetings, each REU student would present about their project, progress, and difficulties. Third, they were required to write a paper step-by-step throughout the summer, including the literature review, conducting the experiments, performing data analysis, and writing the conclusions. Last, they were required to (1) create a poster to summarize their work, (2) present their findings at both a university-wide poster session and an engineering-oriented poster session, and (3) respond to their peers’ questions about their projects. In addition to working on a research project, participants would also attend workshops and field trips related to imaging technology, science and engineering research, and planning for graduate school. Some of these activities were sponsored by the university’s Office of Undergraduate Research and involved participants from other REU and undergraduate research programs. Others provided opportunities for participants and their mentors to come together and exchange ideas and experiences and to begin to establish a research community on themes related to imaging.

Career Development

Students were introduced to research conventions and opportunities through a weekly Career Development series. The program provided lunch to encourage an informal atmosphere with plenty of student-faculty and student-student engagement. Every effort was made to ensure that

the speaker diversity reflected that of the REU students, so that students could envision themselves taking the speakers' paths. Further student-faculty interaction was provided through weekly faculty research seminars. Each week, one faculty member presented brief vignettes of their research interests to the group, enabling students to learn of other imaging related research beyond their own projects.

In addition to the program-related activities, students participated in several University-wide enrichment events. These activities included a weekly brown-bag seminar series on topics such as Ethics, GRE preparation, Getting into Graduate School, and Abstract Writing. Additionally, tours of campus research facilities (e.g. cyclotron, immersive visualization center) were offered. Finally, students were required to participate in two poster sessions at the conclusion of the program—a campus-wide REU poster session and a poster session for participants in College of Engineering summer research programs. Students kept their posters for presentation at national or regional conferences and to display in their home departments to facilitate recruiting.

Social activities

REU students were integrated into the larger university research community—over 200 undergraduates were involved in a dozen REU and other formal summer research programs in 2014. Students were housed with students from these other summer research programs in a modern dormitory that included a fitness center, a movie theater, and a pool. The dormitory was within easy walking distance to the College of Engineering. This housing arrangement along with membership to the University's recreation center provided opportunities for a number of social activities, including intramural softball competitions, rock wall climbing, and weekend trips.

All students also attended the campus-wide barbeque held at the conclusion of the first week to network with summer researchers from a variety of disciplines. TAMU students, who pride themselves on the Aggie tradition of hospitality, were encouraged to act as hosts for our REU students to supplement the usual social events organized at the research-group level. Table 1 provides a sample of scheduled social events, career development workshops, research seminars, and field trip activities.

Table 1. Schedule of Activities

Week 1	Welcome BBQ * Engineering Breakfast * Kick-off Meeting and Orientation * Initial meeting with faculty mentor * Work area tour * Tour of University library and seminar on using library resources * Laboratory safety training
Week 2	Seminar: <i>Getting into Graduate School</i> * Research seminar: <i>Six-Axis, Magnetically levitated instrument for nano particles manipulation</i> (Kim)
Week 3	Seminar: <i>Engineering Innovative Research</i> * Tour: Immersive Visualization Lab * Research seminar: <i>From human walking to bipedal robotic walking to prosthetic design</i> (Ames)
Week 4	Seminar: <i>Funding Graduate School</i> * Cyclotron Institute tour * Field trip to Solectron Texas. L.P., Austin, TX * Research seminar: <i>Design and fabrication of microfluidic microbial fuel cell array</i> (Han)
Week 5	Seminar: <i>Everyday Ethics</i> * Tour: Offshore Technology Research Center * Mid-

	program assessment * Research seminar: <i>Robot failure recovery techniques for smart prosthetic hands driven by myoelectric signals</i> (Robson)
Week 6	Seminar: <i>Students' Rights as Authors</i> * Field trip to NASA Johnson Space Center, Houston, TX * Research seminar: <i>Nano imprint for micro/nano electronic fabrication</i> (Cheng)
Week 7	Seminar: <i>Writing Abstracts</i> * Tour: * Tour: Low-Speed Wind Tunnel facility *
Week 8	Seminar: <i>How to Present Your Research</i> * Tour: Materials & Characterization Facility *
Week 9	Work on poster and final report * Present poster at university-wide REU poster session and College of Engineering poster session *
Week 10	Present report to REU cohort * End-of-program assessment

Activity Highlights

In addition to working on their research projects, participants attended research presentations, career-development workshops, and social activities with other students involved in REU and summer research programs at Texas A&M University. During the last week of the program, they presented their work at a university-wide poster session and completed papers summarizing their research. Figures 1 and 2 show photos from the university-wide poster session sponsored by Texas A&M University's Office of Honors and Undergraduate Research.

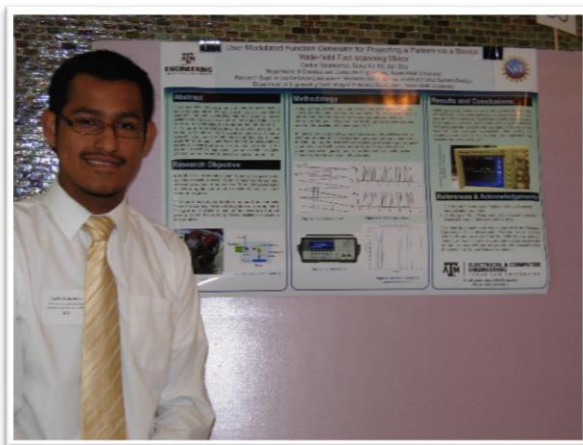


Figure 1. Presenting research to REU cohort.

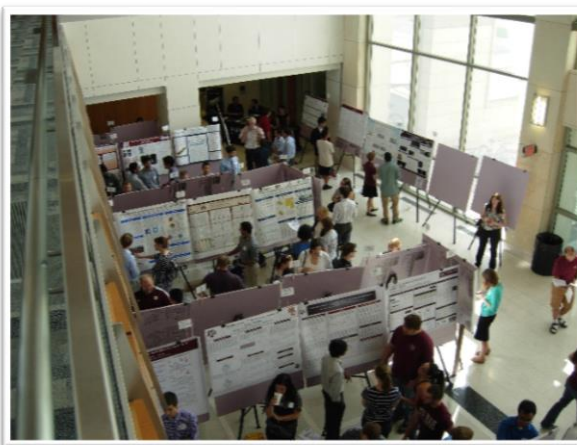


Figure 2. University-wide poster session.

Figure 3 shows an example of a project abstract. A bound volume of all the REU project abstracts was provided each poster session participant. Figure 4 shows a participant inserting chemical samples into a spectrofluorometer at the Materials Characterization Facility and Figure 5 shows her using the spectrofluorometer to measure the light intensity of a chemiluminescent reaction as time passes.

Participant: Thomas Lavastida

Mentor: Dezhen Song

Title: Building a Public Data Set for Vision-Based Simultaneous Localization and Mapping for Indoor Mobile Robots

Abstract: An important problem in Robotics is the idea that a robot can enter a new environment, given no knowledge of the environment before being placed into it, and create a map of the environment as well as know where the robot is currently located and oriented inside that map. This is called Simultaneous Localization and Mapping or just SLAM. The goal of this research project was to create a public data set that will assist further research into SLAM, specifically Vision-based SLAM. The data set will include: video sequences taken by a cell phone camera and the Microsoft Kinect for Windows Sensor of a hallway containing several landmarks, camera calibration data for both the cell phone camera and Kinect, the coordinates of the set of landmarks contained in the hallway, and the locations of the landmarks within selected images from the video sequence. The data set was also going to include the trajectory of the camera sensors at various positions in the video sequence; however accurate results were not achieved due to time constraints.

Figure 3. Sample paper abstract



Figure 4. Inserting chemical samples into a spectrofluorometer.

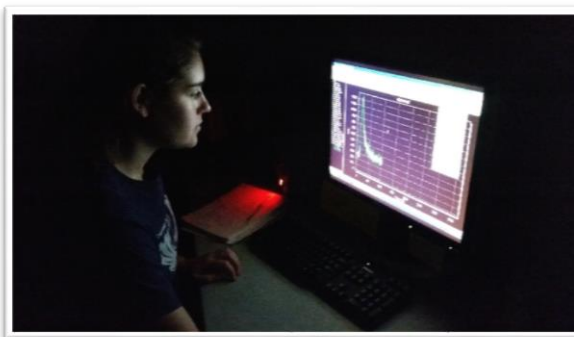


Figure 5. Using spectrofluorometer to measure the light intensity of a chemiluminescent reaction.

Dissemination and Long-term Tracking of Students

As mentioned above, research results were presented at two poster sessions. In addition, some participants' work will be presented at research conferences. To keep track of participants after they completed REU program, we have kept communications open with the students and their advisors. To encourage active involvement of faculty at the students' home campuses, we specifically asked faculty to recommend students for the program, and to be involved in the selection of their student's research project. The PI also maintains contact with participants.

Results

Below are results from a survey sent to the 2014 program participants. The surveys were sent during October of 2014, about two months after they completed the summer program. Completion of the surveys was anonymous and voluntary, and eight of the ten participants responded.

Participants rated their level of agreement with the following statements.

- Doing research confirmed my interest in my field of study.
- Doing research clarified for me which field of study I want to pursue.
- My research experience has prepared me for advanced coursework or thesis work.
- My research experience has prepared me for graduate school.
- My research experience has prepared me for a job.

All eight respondents (100%) agreed that their research experience *clarified for me which field of study I want to pursue*. Six of the eight (75%) agreed that *doing research confirmed my interest in my field of study*, *my research experience has prepared me for graduate school*, and *my research experience has prepared me for a job*. Five of the eight (62.5%) agreed that *my research experience has prepared me for advanced coursework or thesis work*. Responses are summarized in Figure 6 below.

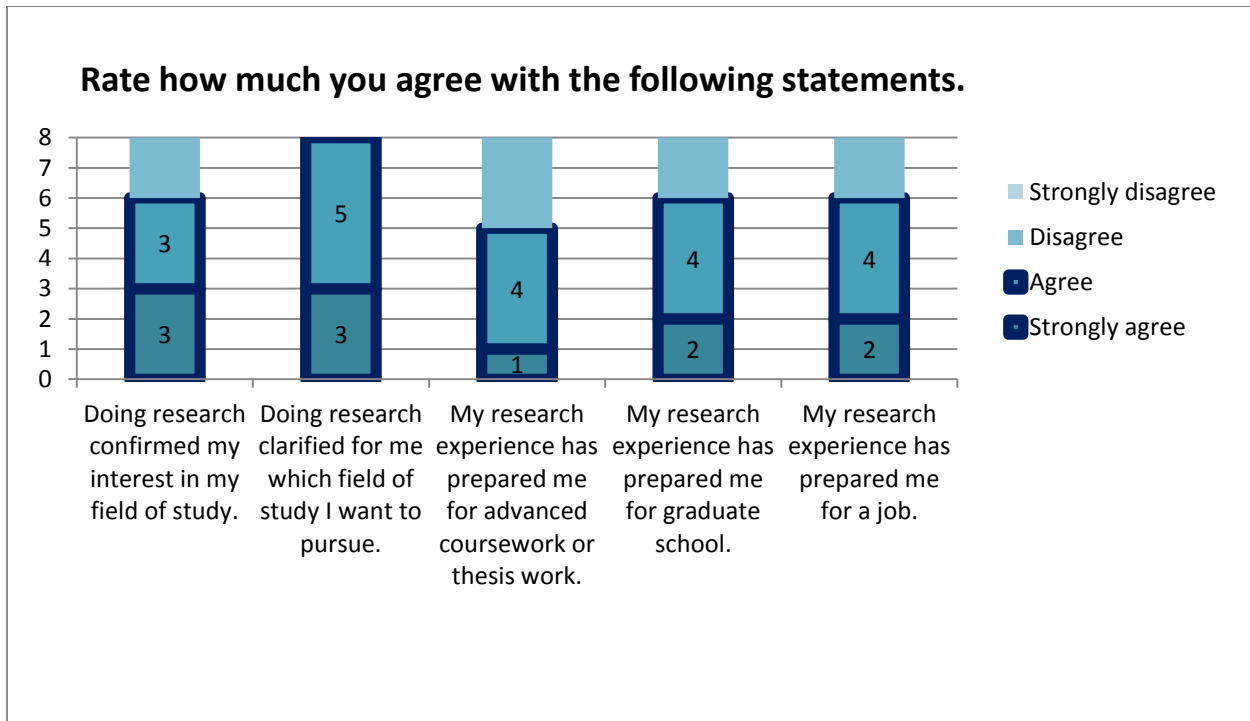


Figure 6. Summary of responses rating agreement with statements about research experience.

Participants were asked: “How did your research experience influence your thinking about future career and graduate school plans? Please explain.” Responses included the following:

- The research experience made me more familiar with a different field of study from those available at my home institution. Consequently, I now have a broader base of actual experience off of which to base my decisions regarding what I want to do after my undergraduate education.
- It has made me more interested in pursuing a graduate degree.
- My research experience clarified what it meant to do research and also solidified my desire to attend graduate school.
- I think it is worth to continue my studies which I wasn't sure about that before
- Before coming into the internship, I was already on the track to attend graduate school for a master's degree, and I contemplated pursuing a Ph. D. However, this internship has taught me that I might prefer to work in an industry setting and that getting a master's degree would likely be sufficient.
- It made me think about it a lot more than before.
- It had not impact on me pursuing graduate school, but did influence a career in corporate research.

Participants were asked: “Did you make other gains from doing research that we didn't mention? If so, please briefly describe these.” Responses included:

- Regardless of the degree of gain, this was my first time conducting semi-independent research. Furthermore, it was my first experience with writing a report for publication submission as well as creating and presenting a research poster.
- This internship really taught me that academic research is very independent. I did not have someone simply giving me orders, but instead I was asked to develop my own goals, methods, and project. So the internship helped me grow as an individual, independent researcher.
- I found out what I didn't want to study.

Participants were asked to rate their level of satisfaction with the following aspects of the research program:

- Research group meetings.
- Financial support.
- Lab tours.
- Group social activities.
- Workshops on preparing for graduate school.
- Poster sessions.

Seven of the 8 respondents (87.5%) reported that they were satisfied with the financial support, lab tours, group social activities, workshops on preparing for graduate school, and poster sessions. Five of the 8 (62.5%) reported that they were satisfied with the research group meetings. Figure 7 summarizes these responses.

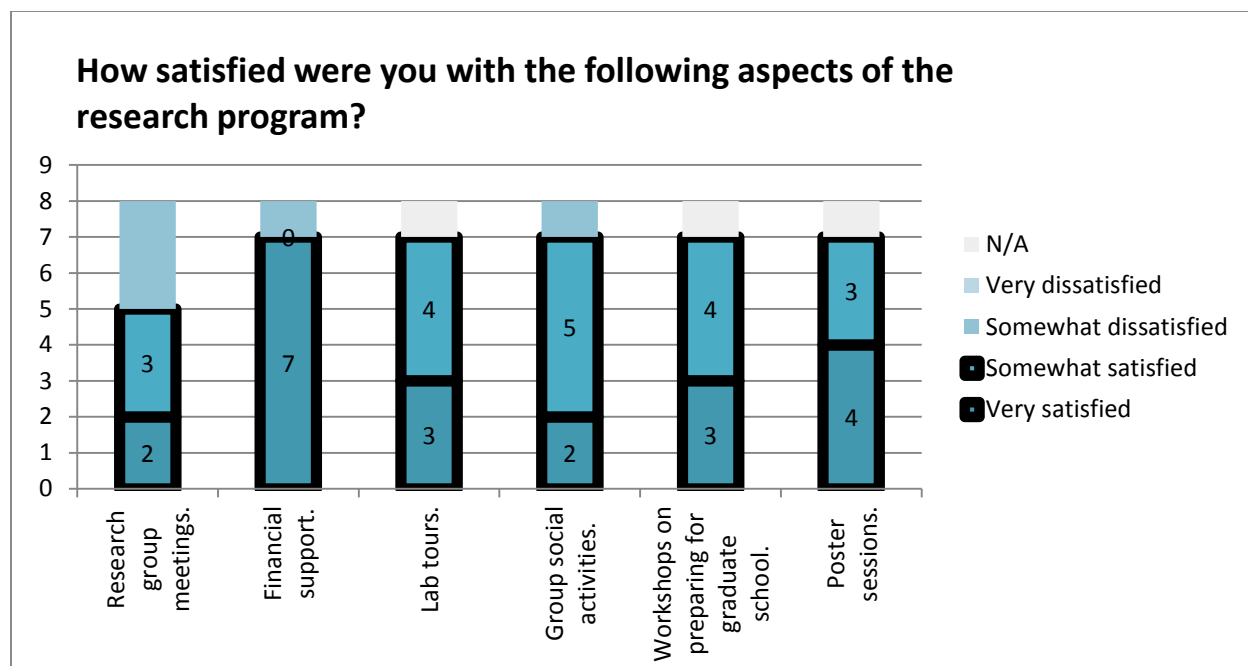


Figure 7. Responses related to satisfaction with various aspects of the REU program.

Participants were asked to describe the most challenging part of the REU experience. Responses included:

- The many "firsts" that the entire research process presented me with.
- Becoming an independent researcher, as the other graduate students and my mentor were not heavily involved in my project.
- Doing individual research was the most challenging part of the experience.
- Not getting as much done as I wanted.
- research in general
- Accessing the lab and the equipment.

Participants were asked to describe the most memorable part of the REU experience. Responses included:

- Actually working on something of interest to some portion of the research community.
- Learning from the graduate students and mentor.
- The poster session was the most memorable part of the entire experience.
- I got to machine some of my own parts
- The poster sessions were really good experiences for me. It increased my confidence with public speaking and poster design.
- poster sessions
- Getting my end of the project to work.

Conclusion and Future Directions

There is an urgent need to increase the number of successful undergraduate students in STEM fields. Studies have shown that involving undergraduate students in research-oriented activities holds some of the answers to increasing student learning, retention, graduation rates and entrance into graduate programs. What is needed are (1) continuous efforts to engage students in course research projects, senior design project and collaborative internship projects, (2) long-term tracking of student learning, research performance and ultimately professional performance and/or graduate work performance, and (3) finding methods that work by investigating the correlation between program elements and success in work or graduate study.

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Note: Asterisk (*) denotes REU participant co-author.

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