Retaining Engineers through Research Entrepreneurship and Advanced-Materials Training (RETREAT): Expansion and Evaluation

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Abstract
The FAMU-FSU College of Engineering Research Experience for Undergraduates (REU) staged at the High-Performance Materials Institute (HPMI) supports undergraduates in various scientific research endeavors with the intent of increasing the number of ensuing student enrollment in engineering graduate programs or pursuit of engineering industry careers. Students hail from a variety of colleges and universities across the United States, from institutions with large, well-established science, technology, engineering, and/or mathematics (STEM) programs to small or nonexistent STEM programs. The main criteria for acceptance are (i) U.S. citizenship or permanent residency and (ii) a grade point average (GPA) of 2.8 or higher. This REU is unique in that it combines training in multiscale, multifunctional composites with entrepreneurship principles and ideals. This is made possible through a successful collaboration between the Industrial and Manufacturing Department, the High-Performance Materials Institute, local entrepreneurs, and the Jim Moran Institute of Global Entrepreneurship at the FSU College of Business (JMI). The entrepreneurial focus has proven highly appealing with students frequently referring to this aspect of the program in their applications. During a ten week summer period, ten candidates engage in short courses in design of experiments, engineering data analysis, and entrepreneurship as well as practical training, research seminars, networking socials, and experimental work. The students subsequently apply this knowledge to write a detailed research report and create a business plan to commercialize their research. At the end of the summer, the students compete in the EngiPreneurship (engineering entrepreneurship) competition where they present their business plans to seasoned judges from JMI, the Office of Intellectual Property and Commercialization, Domi Station, and Tallahassee professionals. At the start and end of the program, students rank their ability and motivation to pursue careers in STEM disciplines and are ranked by their graduate student mentors. The combined foci of research, development, and entrepreneurship have shown to increase student engagement.

Introduction
The Committee on Prospering in the Global Economy of the 21st Century’s report “Rising Above the Gathering Storm” describes the US position of eminence in science and technology as compared to other countries- and how that position is slipping [1]. A major recommendation the committee makes is to recruit and retain scientists and engineers. Lichtenstein et al. report that engineering students are often undecided about their careers, even into their senior year of their degree program [2]. Students receiving bachelor’s degrees in engineering often accept positions outside of engineering, again indicating that retaining engineers is a major concern.
Statistics from the National Science Board and the Bureau of Labor Statistics indicate a specific lack in retention of minorities in technical fields. The number of recipients of bachelor’s degrees in science, technology, engineering, and mathematics (STEM) fields has remained fairly constant from 1991 [3] through 2011 [4], with a constant 20% of engineering degrees being awarded to women [5]. Despite the constant number percentage of degrees awarded each year, the percentage of women in “architecture and engineering occupations” is slowly rising, from 12.9% in 2011 [6] to 15.4% in 2014 [7], indicating that retention of female engineers is slowly improving. However, this percentage (15.4%) is still dramatically lower than the percentage of women in the workforce (47% [7]). Similar discrepancies in education and employment are observed for racial minorities.

The Retaining Engineers through Research Entrepreneurship and Advanced-Materials Training (RETREAT) Research Experience for Undergraduates (REU) program is designed to address the retention concern. This program exposes students to a number of specific engineering applications through a variety of advanced materials research projects. Each student is also matched with a faculty member and a graduate student, who mentor the student through the stages of the RETREAT program and how the students’ skills and interests could be well-suited to a technical position in industry or a graduate degree in engineering. The entrepreneurial twist is included to reinvigorate upper level students and encourage their continuation in a STEM field. This report provides an outline of how students are recruited and selected – with particular attention as to how the program has been expanded from previous years [8], the curriculum and projects the students work on throughout the ten week program, and outcomes of the program.

**Student Recruitment and Selection: Expansion**

*Recruitment*

Students are recruited for the RETREAT program in a number of ways, including both in person and online interactions. In person interactions include connecting with local students through employment opportunities at Florida State University’s (FSU’s) High-Performance Materials Institute (HPMI) – pictured in Figure 1 – and presentations at other institutions. Online interactions include reaching out to educational partners across the country and maintaining an active web presence. The recruitment process is also currently being expanded to reach more students, as described below.
The Industrial and Manufacturing Engineering (IME) Department at the Florida Agricultural and Mechanical University – Florida State University (FAMU-FSU) College of Engineering and HPMI support dozens of undergraduate research assistants (RAs) each semester, from FAMU, FSU, and Tallahassee Community College (TCC). These students work on cutting edge research in materials and industrial engineering, often working with their graduate student and faculty mentors to publish peer-reviewed journal articles about their work. Many RAs earn Honors in the Major by writing and defending a research thesis. This network of undergraduate RAs has proven a useful tool for solicitation of applicants to the RETREAT program, both of these students and of other students they know to whom they can recommend the research at HPMI. To reach more students with personal connections, the coordination team visited as many campus as possible to showcase the program. Presently, campus visits are limited to campuses in the south east US due to cost of travel, but as program coordinators attend conferences and collaborating research institutions, these visits can be expanded to include colleges and universities farther away.

Campus visits are followed with emails with application information to targeted campuses and programs. Email allows direct connection with students after presentations have occurred, giving
them the opportunity to learn more about the program and providing a convenient link to the application page. Program announcements are also sent to contacts at institutions across the country, with the hope of providing the same information and convenience to students from unvisited institutions. The program’s web presence includes a website hosted by the FAMU-FSU College of Engineering – including testimonial videos from past participants, a listing in the National Science Foundation’s REU Site directory, and a LinkedIn group.

Expansion of the student recruitment process is a work in progress, but so far includes faculty nominations, student-to-student connections, and continued maintenance and upgrade of the program’s electronic presence. High-performing and/or highly interested students are identified by IME professors and HPMI research faculty during academic courses and other interactions. Faculty are encouraged to nominate students with whom they would like to work. Nominations for the summer 2016 year include local students (from FAMU, FSU, and TCC) as well as students from a number of other institutions. As students participate in and complete the RETREAT program, they are asked to become student ambassadors for the programs. Ambassadorship includes finding and providing contact information for contacts at their home colleges and universities who could send out the program announcement in future years and personally sending out the program announcement to professors and student groups who may be able to forward the information. In future years, student ambassadors will be provided presentation materials, so they may give presentations about the RETREAT program at their home institutions. The program’s electronic presence is constantly being expanded, through LinkedIn connections, website updates, and networking. The LinkedIn group provides a means to provide past participants current program information. The NSF and FAMU-FSU websites have been updated to provide a more accurate description of the program (highlighting the variety of research projects), with the FAMU-FSU website now also including links to brief video interviews with past participants (starting in 2015) where they describe their research project, the program, and the effect the program had on their future plans. As the program’s network expands, more and more students can be reached. For the 2016 program year, particular attention has been given to reaching out to Engineering Diversity Programs, Tribal Colleges and Universities, and Historically Black Colleges and Universities. Further expansion will include reaching out to Hispanic, Alaska Native, Native Hawaiian, and other minority-serving institutions.
Marketing Outcomes

One metric of success of marketing is the number of applicants and number of institutions contacted during the marketing process. Marketing effort has expanded from 47 colleges and universities in previous years to over 150 institutions for the summer 2016 program. A second metric of success of marketing is through the number of students engaged and their home institutions, which can be monitored via the applicant pool. This data is only available for 2015 onwards. Table 1 summarizes the number of schools represented by each year’s pool of applicants. In 2015, the application was open from November until mid-March, and a total of 44 students applied for the program. The 2016 application opened in November and closed mid-February, with a total of 88 students applying for the program. Not only did the number of applicants double, but the number of schools represented in the applicant pool also doubled, indicating marketing expansion efforts were successful.

Table 1: Number of schools represented by applicant pool each program year

<table>
<thead>
<tr>
<th>Program Year</th>
<th>Number of Schools Represented in Applicant Pool, (Total Number of Applicants)</th>
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<tbody>
<tr>
<td>2015</td>
<td>33, (44)</td>
</tr>
<tr>
<td>2016</td>
<td>65, (88)</td>
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Selection

Each year of the RETREAT program, 10 students are selected to participate in the internship. The main limitation on student selection is that they must be a US citizen or permanent resident. Applications are initially considered based on GPA, statement of purpose, resume, and recommendation letters. One-on-one interviews (by telephone or in person) are then conducted for top applicants, to better discern their motivations, interests, and potential benefit from the program.

In the past, the grade point average (GPA) requirement has been 3.2/4.0. In 2016 the minimum GPA requirement has been lowered to 2.8/4.0, so students who maintain interest in engineering research are incited to apply even if they may be struggling with some aspects of their engineering curriculum. The selection of students does not rely on academic performance alone:
students with a perceived interest in solving real problems with their STEM knowledge and
students with demonstrated innovation and independence are given particular attention during
the selection process. One goal of the program is to motivate struggling students to become high
achievers.

In the past, completion of the junior year in a STEM discipline was required; acceptance has
since been expanded to include students who have completed their sophomore year in any
discipline. Rising juniors are considered since they have more time to reevaluate their future
career plans than do rising seniors, and may benefit more from the REU program. Students in
any discipline are considered because their application to the program indicates a strong interest
in engineering research; coming from a non-engineering field but exhibiting such interest is the
basis for a strong application. Particular attention is given to students hailing from institutions
with small or nonexistent STEM programs. Students from these institutions may not have any
past engineering or research experience, because they do not have easy access to such a program.
Should they be a good match for the RETREAT program, their experience could be pivotal in
their decision to pursue a STEM (particularly engineering) graduate degree and/or career.

**Curriculum**

*Laboratory Trainings*

To prepare for the summer of intensive research, interns are trained in a number of topics,
including design of experiments, safety practices, research methods, and use of specific
equipment and processes. A short course (six 2.5 hour class meetings) in statistics, design of
experiments, and engineering data analysis provides a basis for all interns to conduct statistically
relevant research, no matter their past education. FSU Environmental Health and Safety
personnel provide Hazardous Waste Awareness, Laboratory Safety, and Hazard Communication
training for the interns. A faculty member provides a research methodology seminar, covering
responsible conduct of research, pictured in Figure 2.
Figure 2: Responsible Conduct of Research Training

These trainings are completed with training on the utilization, manufacture, and characterization of multi-scale and multifunctional advanced composites. Experts provide group and individual trainings on composite manufacturing – pictured in Figure 3, dynamic mechanical analysis, thermo-gravimetric analysis, and chemical safety training. This is complemented by one-on-one instruction about research methods specific to each project, such as scanning electron microscopy, waterjet training, and C-scan mapping.

Figure 3: Hands-on laboratory training

Facility Tours and Field Trips

Technical trainings are accompanied by facility tours and field trips, both technical and social. Over the first several weeks of the program, interns are provided tours of FSU’s High-Performance Materials Institute at the Materials Research Building, the Aero-Propulsion, Mechatronics and Energy Building, and the Center for Advanced Power Systems, as pictured in Figure 4.
Interns are also given a tour of the National High Magnetic Field Laboratory (affectionately known as the MagLab). Conveniently located down the street from the REU site, the MagLab is the largest and highest-powered magnet laboratory in the world. As pictured in Figure 5, interns are provided opportunities to directly ask experts questions about the facility and research projects.

In conjunction with another internship program (funded by the Air Force Research Laboratory), RETREAT interns visit Eglin Air Force Base to learn about engineered materials at the Department of Defense, as pictured in Figure 6. In addition to a brief seminar on general research topics undertaken by the Munitions Directorate, interns are able to tour the base and nearby facilities, view demonstrations of current research, and network with research professionals.
The RETREAT program also provides social opportunities and field trips for the interns. Each week, HPMI hosts a networking social for summer interns, undergraduate research assistants, graduate student researchers, staff members, and research faculty, as pictured in Figure 7.

Other social activities are also planned, including field trips to Edward Ball Wakulla Springs State Park and Panama City Beach, shown in Figure 8.
Research Projects

Throughout the ten weeks of the program, interns conduct hands-on research for individual projects. Before the program starts, interns are matched with a faculty mentor and a graduate student mentor. They are provided background reading material to familiarize themselves with their respective projects to prepare for the program. Project subjects include “big data” analysis, industrial optimization, and manufacturing and characterization of a variety of materials from nanoparticles to multi-scale, multifunctional composite structures. Students present their work to HPMI researchers, through two oral presentations throughout the summer and a final poster presentation, as shown in Figure 9.
Every student is required to submit a research lab report at the end of the summer, and support is provided for developing their work into journal publications. As students work on their research projects, pictured in Figure 10, their focus is to understand the potential applications of their work. To this end, this program includes an entrepreneurship lecture series and competition.
**EngiPreneurship Lecture Series**

A major component of the RETREAT program is a focus on entrepreneurship. The entrepreneurs-in-residence of the Industrial and Manufacturing Engineering (IME) Department and HPMI collaborate with the Jim Moran Institute of Global Entrepreneurship and the FSU College of Business (JMI), Domi Station, and the Office of Intellectual Property and Commercialization to connect interns with local experts and entrepreneurs. A seminar series brings local businessmen and -women in to talk about entrepreneurship principles and ideals and trains students in basic business planning practices. The students develop a business model to commercialize their research. These models are presented at an end-of-program EngiPreneurship (engineering entrepreneurship) competition consisting in a “Shark Tank” style pitch contest. The competition is judged by a panel of entrepreneurs and local industry experts, pictured in Figure 11.

![Figure 11: Local experts judging the EngiPreneurship Competition](image)

Expansion

Expansion of the program curriculum began in 2015 by reaching out to additional industry partners. This initiative began with tours at Danfoss Turbocor, shown in Figure 12. Future expansion will include additional trainings. Before the interns arrive, graduate students will be given mentorship training. The interns will be provided library and database training, as well as scientific presentations and writing. Other ideas being explored is social networking training (focusing on LinkedIn use) and additional facility tours, such as the FSU Marine Lab.
Figure 12: Interns at Danfoss Turbocor

Student Outcomes

Figure 13 shows the past interns from 2011, 2012, 2013, and 2015. These students hail from institutions across the country. Represented schools include minority-serving institutions, public and private institutions, community colleges and Ivy League schools. The home institutions of the past year interns are summarized in Table 2.

Figure 13: Group photos from 2011, 2012, 2013, and 2015
Table 2: Home institutions of past interns

<table>
<thead>
<tr>
<th>Year</th>
<th>Home Institutions of Interns</th>
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<tbody>
<tr>
<td>2011</td>
<td>Brown University, Florida State University, Michigan State University, Simpson College, University of Maryland – Baltimore, University of Massachusetts – Amherst, University of Rochester</td>
</tr>
<tr>
<td>2012</td>
<td>Austin Peay, Cornell University, Florida State University, Georgia Tech, Notre Dame, University of Maryland – College Park, University of Massachusetts – Amherst, University of Miami, University of Oklahoma</td>
</tr>
<tr>
<td>2013</td>
<td>Cooper Union for the Advancement of Science and Art, Clemson University, Florida State University, North Carolina State University, Rutgers University – New Brunswick, University of Miami, University of Notre Dame, University of North Texas, Vanderbilt University</td>
</tr>
<tr>
<td>2015</td>
<td>Beloit College, Florida Institute of Technology, Florida State University, Rutgers University, Tallahassee Community College, University of Alabama – Birmingham, University of Maryland – Baltimore, University of North Carolina – Ashville, University of Redlands, University of Southern California</td>
</tr>
</tbody>
</table>

Several methods are used to identify the student outcomes of this program. In 2013, an electronic survey was sent out to 2011 and 2012 interns. As an additional measure of the effect of the program, pre- and post- surveys were implemented in 2015. As a secondary data point, the students’ faculty mentors were asked to rate their interns on the same characteristics as the interns rated themselves, again in the beginning of the program and at the end of the program. Additionally, the program coordinator calls interns from the past three years once a year and asks about their current positions and plans for the immediate future. All interns are encouraged to connect with the program coordinator via LinkedIn, which allows tracking of participants after the three year annual call period.

In the 2013 survey, students indicated they felt the program had a positive impact on their decision to stay in a STEM field. Selected quotes from the past interns follow.

“The internship solidified my passion for the sciences.” – 2012
“The REU program gave me a thorough introduction to research and how life as a graduate student might be... which was a factor in my decision to pursue a PhD.” – 2012

“Participation in the REU program cemented my decision to pursue a PhD after graduation.” – 2012

“I have always thought that I would remain [in STEM], and participating in the program just further supported that notion.” – 2011

“Participating in this REU program really showed me the diversity of my degree and all the possibilities/opportunities that are available to me.” – 2011

The surveys implemented in 2015 have students rate how strongly they agree with statements like “I am extremely confident in my ability to do research” and “I can confidently present my work (oral communication)”. The scale is from 1 (strongly disagree) to 5 (strongly agree). As soon as the students arrive in May, they fill out the pre-survey. After the final competition in August, they fill out the post-survey. Selected data points from this survey set are shown in Figure 14. The intern’s average self-rating of research confidence rose from 3.3 to 4.4. The interns’ average self-rating of oral presentation ability increased from 3.5 to 4.1. Interns’ desire to pursue graduate education increased from 3.9 to 4.25 in the post survey. As a final note, the two highest-rated statements in the post-survey were “I have a keen interest in innovations” (average score of 4.9) and “I will likely pursue a career in science and technology” (average score of 5). These numbers represent a 0 and 0.1 point increase, respectively, for the two questions, since students started out interested in innovations and STEM (according to the pre-survey). This is unsurprising due to the expected selection bias of students applying for an engineering research internship focused on entrepreneurship.
Faculty’s ratings of interns’ knowledge of research started out at an average of 3.3 and increased to 4.3. Faculty’s confidence in the students’ ability to present orally increased from 4.3 to 4.7. Perhaps most interestingly, where students’ rated themselves at an average score of 4.25 at the end of the program for their ability to apply research methods and tools (an increase of 0.45 points), faculty rated the students’ abilities at 4.4 (a 0.8 point increase from the earlier survey).
Figure 15: Faculty average ratings of interns before and after the program

The current status of the 40 participants in the RETREAT program (2011, 2012, 2013, 2015) have been tracked. Their statuses (at time of writing) are summarized in Figure 16. 11 are finishing their undergraduate degrees, 3 are in master degree programs, 9 are in PhD degree programs, 14 are in industry, and the current positions of the final 3 are unknown. 2 of the PhD students hold master degrees. 6 of those in industry hold master degrees, leaving 8 students (20%) who did not pursue graduate degrees. 100% of past interns hold a position in a STEM field, with 2 currently managers at STEM companies.

Figure 16: Current positions of past interns

Conclusion

The FAMU-FSU College of Engineering’s IME Department REU site at the High-Performance Materials Institute has supported undergraduate research since 2011. As the program is expanded to reach and include more students, the program is able to positively impact the selected interns...
each year. Hands-on laboratory activities enhance the students’ understanding of scientific concepts, motivate their interests and curiosities, and improve their technical skills. Data shows an increase in students’ perceived research abilities and confidence with presenting their work. 100% of RETREAT participants have continued in STEM fields, and 80% of participants have completed or are pursuing a graduate education. The combination of research and entrepreneurship training and mentorship serves to attract and engage students. The described plans for expansion will serve to reach and motivate additional students, stimulating their interest in STEM disciplines.

References