NSF-Retaining Engineers through Research Entrepreneurship and Advanced–Materials Training (RETREAT)

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Dr. David O. Olawale received his doctorate degree from the Department of Industrial and Manufacturing Engineering, Florida State University. At FSU, his research focuses on the development of Triboluminescent Multifunctional Cementitious Composites (TMCC). These are cementitious composites with both structural and in-situ damage sensing capabilities. They will provide our civil infrastructure systems like bridges and dams with real time damage monitoring capability similar to that found in biological systems.

His research work has led to the filing of a patent application, publication of journal articles and presentation of conference papers. The technology is also on the path to commercialization. The technology won 2nd place position in the highly competitive InNOLEvation business plan competition (2012) organized by the Jim Moran Institute for Global Entrepreneurship and resulted in the formation of a technology startup company.

In addition, David Olawale served as the Assistant Coordinator for the NSF-sponsored research experience for undergraduates (RETREAT) program and also the Air Force Research Laboratory-sponsored internship (DREAM) program at the High Performance Materials Institute (HPMI) from 2010-2012. He currently focuses his research efforts on innovative sensor systems and multifunctional nanocomposites.

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Dr. Okenwa Okoli is Professor and Chair of Industrial and Manufacturing Engineering at the Florida-A&M – Florida State University College of Engineering. He has worked extensively in the development of affordable and functional composite manufacturing technologies for which he has received several awards. With the increased utilization of composites in critical structures, Dr. Okoli's innovative research efforts include the development of integrated structural health sensing within advanced composites and concrete structures. He also focuses on the development of scalable technologies for the manufacture of customizable multiscale and multifunctional composite structures, integrated PV sensors and innovative 3D energy conversion systems. He has extensive experience in the transient non-linear dynamic analysis of fiber reinforced composite structures. He has 7 US patent applications (awarded and pending) in the areas of advanced composites and multiscale composites manufacture, structural ceramics, and ubiquitous real-time structural health monitoring. He is a chartered engineer and a chartered scientist.

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Abstract

The FAMU-FSU College of Engineering REU site was established with the goal of persuading an increased number of engineering students to continue into engineering careers in industry or proceed to postgraduate training in materials engineering research post baccalaureate. The uniqueness of this REU site lies in our program's ability to combine training in multiscale multifunctional advanced composites with entrepreneurship principles and ideals. It involves a successful collaboration between the Industrial and Manufacturing Department and the Jim Moran Institute "JMI" of Global Entrepreneurship (FSU College of Business). The appeal and competitiveness of the program to STEM undergraduates is evident from the over 90 applicants annually from all branches of engineering and the sciences. Each summer since 2011, ten successful candidates have completed several structured, vigorous, yet fun-filled sessions of class work, seminars, practical training, experimental work, and presentations through the 10 weeks of the program. Each summer, the REU RETREAT program ended with an EngiPreneurship (Engineering Entrepreneurship) Competition where the interns presented their business plan to commercialize their research work to a seasoned set of panelists from the JMI and the Office of Intellectual Property and Commercialization of FSU. At the end of the RETREAT program, the students were motivated to pursue careers in the STEM disciplines and equipped with the capability to identify needs/problems, develop innovative solutions/products at competitive prices, and develop a business plan to successfully commercialize them.

Introduction

The report “Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future” drew much attention to concerns over the declining global competitiveness of the United States in Science and Technology [1]. However, Lichtenstein et al. [2] reported that the decline noticed in the STEM (Science, Technology, Engineering, and Mathematics) disciplines was not due to a decline in intake or retention of students, but due to broad unfocused interests found in students late into their senior year. They reported that students who complete a major in engineering are not necessarily committed to careers in engineering or even STEM. Students easily migrate into careers outside the STEM disciplines. The REU site used advanced materials with an entrepreneurial twist to refocus senior students pursuing careers and graduate programs in STEM fields.

The field of advanced materials is very broad; however, the REU curriculum focused the student at several key, real world application-based endeavors. Several projects involving the processing and applications of nanomaterials and multiscale-multifunctional composite materials were chosen to be student research project initiatives. These were selected to equip the students with knowledge in the synthesis and characterization of nanomaterials and their utilization in manufacturing processes. Students learned the fundamental synthesis mechanisms of nanomaterials critical to controllable and consistent production. The students also learned the necessity of methodologies for a wide range of processes to determine the best parameters for production of multiscale composites. Thorough understanding and further verification of these multiscale materials were attained through the application of statistical modeling of processes and property variations.

Curriculum

The REU site guided students through a combination of seminars and lab experiences. The seminars provided fundamental knowledge to assist in their research and included topics in Research Methods and Ethics, Health and Safety, Statistical Analysis, Engineering Data Analysis, Experimental Design, and the use of statistical software packages. Seminars on Technology Entrepreneurship and Commercialization (TEC) were used to enhance the understanding of the relevance of research innovations and graduate research degrees to the business environment. Although the TEC seminars took place during the first four weeks of the

program, the students were required to discuss their progress with the TEC faculty mentor to guide them in getting their product to “market.” The outcomes of the program were assessed through the EngiPreneur Competition where each student presented his/her work (and product) and gave an assessment of its market potential and pit falls suggesting what needs to be done to successfully take the product to market. A panel of entrepreneurs and industry product champions judged the competition each year and the winners awarded great prizes (see Figure 1).

Figure 1 EngiPreneurship (Engineering Entrepreneurship) Competition winners and summer culmination

Student Recruitment and Selection

Over the past thirteen years, the PI and other senior faculty at the Department of Industrial and Manufacturing Engineering (IME) through the High-Performance Materials Institute (HPMI) have encouraged an increasing pool of quality undergraduate students to participate in innovative materials research of industrial significance. HPMI regularly engages undergraduates in advanced composites and nanocomposites research. A total of thirteen undergraduates worked as paid research assistants at HPMI in the Fall 2013 semester. Since 2001, our research group has trained over 170 undergraduate research students. The undergraduate research assistants are encouraged to participate in the Honors in the Major initiative culminating in a research thesis. This has served as a useful recruiting tool into our graduate program.

Our REU RETREAT focus has been on advanced composites and nanomaterials. The advent of ‘Generation III’ composites, which are multiscale, multifunctional, inherently sensing, morphing etc. materials, has led to the need for recruiting more versatile, innovative, quick, independent

thinking, hands-on researchers to maintain and skyrocket the technological lead of the United States for the 21st Century and beyond. This requires that the selection of students is not based on academic performance alone. Although the success of our internship programs may be attributed to the high quality of participants selected, with an average GPA of over 3.6/4, our selection criteria included a requirement for a minimum GPA of just 3.2. Furthermore, we selected participants based on their perceived interest in implementing the knowledge fundamentals from their STEM disciplines to solving real world problems. In addition to utilizing our contacts in target programs, our coordination team went to as many campuses as we could to showcase our program. We followed through with an e-mail campaign to targeted campuses and programs, as well as through development of a web site. Our web presence has testimonial videos from our current undergraduate and graduate RAs who served as lab partners and mentors to the REU summer students. The coordination team organized several on campus visits and set up a direct link to e-mail the required documents. In both 2011 and 2012, recruitment was sought from the southeastern US, although applications came in from all over the country. Applications numbered about 90 each year. Our recruitment included road trips to minority schools and to those without graduate programs.

To facilitate optimal actualization of program objectives, completion of the junior year in a STEM discipline was also required. Yes, it would have been easier to select those who had prior experience, but that was not necessary, as we were able to discern from their personal statements, references, and one-to-one interviews (by telephone or in person) their interests in applying their knowledge. Nonetheless, our future efforts will include those with a minimum GPA of 2.8 who have at least 2 years to graduation. Our goal is to utilize our program to transform these students into high achievers. We have already begun this transformational effort through funding from the Department of Energy (this will be reported elsewhere).

Training

The interns were trained on the safe use of equipment and processes pertinent to their research. The training was conducted by HPMI faculty and researchers. Some of the training sessions may be seen in Figure 2.

Figure 2: Training in progress

Outcomes

The first year (2011) of the REU RETREAT program involved ten students from seven schools (Brown University, Florida State University, Michigan State University, Simpson College, University of Maryland Baltimore County, University of Massachusetts at Amherst, University of Rochester). Nine of them were from outside FSU. The group of interns comprised four (4) female and six (6) male students. The projects and faculty mentors from the 2011 RETREAT program are shown in Table 1.

Table 1: 2011 REU projects

Projects	Faculty Mentor
Enabling Economic Production of Open Ended CNTs Via Ultramicrotome Cutting	Richard Liang
Towards Green Energy via Characterizing SWCNTs and Material Performance	Tao Liu
Engineering Photoluminescent Behavior in SWNTs	Tao Liu
Synthesis and Characterization of TiO_2-coated Carbon Nanotube Yarns	Okenwa Okoli
Impact Characterization of In-situ Triboluminescent Optical Fiber (ITOF) Sensor for Damage Detection in Cemenitious Composites	Okenwa Okoli
Integrated Sensor Systems for Advanced Composites	Arda Vanli
Strain Sensors Fabricated by Aerosol-jet Printing Technique	Ben Wang
Novel Supercapacitor Electrodes and Synthesis	Changchun Zeng
Sensors in Prosthetic Liners	Chuck Zhang
Flexible Carbon Nanotube Speakers	Mei Zhang

A major measure of success is the matriculation of students into graduate engineering research programs, and/or the progression to engineering and technology careers. Data from our 2011

program given in Table 2 shows that 70% of the interns graduated in the spring of 2012; the remaining graduated in 2013. Of the 2012 graduates, 57% (4 of 7) were accepted into a STEM graduate program. 43% (3 of 7) progressed to STEM related careers. The remaining three graduated in 2013 with 66% (2 of 3) graduates pursuing STEM careers, and 33% (1 of 3) intends to attend a STEM related graduate program as a doctoral student.

Table 2: RETREAT 2011 – Next steps

Intern	Graduation	Next Steps
1	May 12	Pursuing MS degree at Brown University and will seek STEM career
2	May 12	Enrolled in FSU grad program in Materials Science
3	May 12	PhD student at the University of Minnesota, researching organic photovoltaic materials
4	May 13	PhD student at Notre Dame
5	May 13	Pursuing STEM career
6	May 12	Grad student at Columbia University in materials science within the Applied Physics and Math Department
7	May 13	Employed in a technology company
8	May 12	Pursuing a career in the biotech sector
9	May 12	Working in the semi-conductor manufacturing/quality control/design/processing area
10	May 12	Working as an aerospace contractor

In an interview (April 2012), the interns indicated that the REU RETREAT program further exposed them to the benefits of graduate research and kept them interested in STEM disciplines. One of such comments is that by Max Terban who has since matriculated to the Materials Science and Engineering graduate program at Columbia University.

"My time spent at HPMI's RETREAT REU was an invaluable step in the development of my own personal educational and career goals. It was a healthy dose of first hand research experience mixed with numerous opportunities to advance skills in communication and make new friends. It also provided the insights into product development and industrial entrepreneurship that no other program even touches. It was a great experience and a milestone that I will forever build upon as my career develops." Maxwell Terban (UMass)

Figure 3: Welcoming the interns to RETREAT 2012!

Figure 3 shows the RETREAT 2012 interns on their first day attending seminars. Table 3 shows the research projects undertaken and the respective faculty mentors.

Table 3: RETREAT 2012 Projects by interns and faculty mentor

Projects	Faculty Mentor
Development of a Moisture Sensor for a Multifunctional Composite Structure	Richard Liang
Thermo-Mechanical Characterization of ZnS:Mn-Epoxy System for Structural Health Monitoring	Okenwa Okoli
Triboluminescent Crystal Synthesis	Okenwa Okoli
Analysis of Human Dynamics Using Smartphone Data	Chiwoo Park
Structural Characterization of Single-Walled Carbon Nanotubes	Tao Liu
EMI Shielding in Composites with Frequency Filters	J.G. Park
Damage Detection in Carbon Fiber Composite Materials Using Lamb Waves	Arda Vanli
Polyurethane Foam for Volume Management in Prosthetic Sockets	Chad Zeng
Alteration of 3D Printing Resin and Auxetic Structure Design	Chuck Zhang
Carbon Nanotube (CNT) Yarn	Mei Zhang

The RETREAT 2012 data given in Table 4 shows information on the ten students from 9 schools and 6 STEM disciplines. During the selection process, efforts were made to create a fair balance in gender and ethnicity resulting in 4 females and 6 males as reported in Table 4. Two were African Americans. From Table 4, it can be seen that 60% of the interns graduated by the spring semester of 2013 (including one in a BS-MS program); the remaining will graduate in 2014. Of the 2013 graduates, 83% (5 of 6) were accepted into STEM graduate programs. 17% (1 of 6) has progressed into a STEM related (manufacturing) career. All four of the 2014 expected graduates (100%) intend to attend a STEM related graduate program. From a recent interview (May 2013), the interns indicated that the REU RETREAT program further exposed them to the benefits of graduate research and kept them interested in STEM disciplines.

Table 4: RETREAT 2012 data

Intern	Graduation	Next Steps
1	May 13	PhD student at University of Oklahoma in GeoPhysics
2	May 13	PhD student at Yale University in Bio Statistics
3	May 13	PhD student at FSU in Mechanical Engineering
4	May 13	MS student at FSU in Mechanical Engineering
5	May 13	PhD student at FSU in Manufacturing Engineering
6	May 14	Plans to attend STEM graduate program
7	May 14	Plans to pursue PhD in Engineering (Industrial, Aerospace, or Materials Science)
8	May 14	Plans to pursue MS in Mechanical Engineering
9	December 12	Manufacturing Engineer at Koyo Bearings in Cairo Georgia
10	May 14	Plans to attend STEM graduate program

Intern Feedback (May 2013)

Some of the feedback from the interns are highlighted below.

I thought the program was a great way to learn about different kinds of research and the opportunities available with an education in the STEM fields. I really liked the entrepreneurship aspect of the program, as this is something I have not come across anywhere else in my undergraduate career.

-Briana Cameron (2012 Intern)

Participating in this REU program really showed me the diversity of my degree and all the possibilities/opportunities that are available to me. At one point, I was going to change my major. However, this REU in particular showed me that I can be qualified in any field. It really helped me morally to stick with my engineering program as well, as I met upper classmen who went through the same struggles that I faced that year. They encouraged me to never give up! Still to this day, I keep in contact with a few of my fellow REU members! This REU also allowed me to apply my classroom knowledge to a real life application. Overall, it was a great experience and it definitely contributed to my decision to remain in the STEM field.

-Rosilyn Chirayath (2011 Intern)

I enjoyed planning and participating with the project, appreciated the facilities, and liked the faculty. I am glad we had the weekly socials where we had a chance to talk to people who work full time at HPMI. I am glad we had opportunities to meet and mix with the other summer research program. I liked that both programs were housed in the same dorm. I enjoyed the picnic at Wakulla Springs.

-Margaret Scheiner (2012 Intern)

Conclusion

Hands-on laboratory activities as shown in Figure 4 are indispensible in science and engineering education. Well-designed laboratory activities enhance the students' understanding of scientific concepts, motivate their interests and curiosities, and improve their scientific practical skills and problem solving capabilities. In the execution of our REU program, instead of giving the students a "cook-book" list of experimental tasks to let them follow, the PI's worked closely with

the students to design, implement, analyze, and interpret the experimental results and illustrate the underlying scientific principles. This not only gave the students opportunities to utilize equipment and materials, but also fostered their scientific enquiry abilities through making observations, posing researchable questions, planning investigations, reviewing existing experimental evidence, using tools to gather, analyze, and interpret data, proposing answers and explanations, and predicting and communicating the results.

Figure 4: Interns at work

A critical component of the REU program is to nurture the undergraduate students to develop their analytical skills, establish a scientific problem-solving methodology, appreciate the importance of higher education in solving complex problems, and attract and engage them in STEM graduate studies, and/or STEM careers. We have successfully utilized the entrepreneurship component to achieve our goals of attracting and keeping the interest of students in the STEM disciplines.

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