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Long-Term Assessment After More than a Decade of Involving Undergraduate Students in an REU Program

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Introduction

Research experiences have long been known to increase student motivation, confidence and retention in the science, technology, engineering and math (STEM) fields. Since the summer of 2006, the department of Mechanical Engineering at Oakland University (OU) has been organizing a research experience for undergraduates (REU) program that has been successful at recruiting underrepresented undergraduates in engineering – women in particular. Funded through the National Science Foundation REU program, this summer REU program seeks to address the nationwide problem of the under-representation of women and minorities in STEM by involving undergraduate students from across the U.S. in automotive-related research projects for 10 weeks during the summer [1-3]. Ultimately, the goal is to engage participants in rewarding automotive research experiences that motivate them to pursue graduate studies and embark on careers in in industry, government or academia.

REU programs are designed around the needs of the undergraduate participants. The research projects, seminars, laboratory/industry tours, meetings with mentors, networking events and other activities are all set up to maximize the positive impact of a research experience on the students. Numerous studies have shown that active participation in hands-on undergraduate research is one of the most effective ways to attract and retain talented undergraduate students, to motivate them towards pursuing careers and advanced degrees in engineering and science, to help them feel more connected to their educational experience and to provide them with a greater sense of empowerment as learners [4-11].

Since its inception in 2006, a total of 92 students from 64 different universities have taken part in the Automotive and Energy Research and Industrial Mentorship (AERIM) REU program. While advertised and open to students of all genders and ethnic backgrounds, this program has been successful at recruiting a diverse pool of undergraduate students, with underrepresented groups in engineering (women in particular) representing 70% of the participants . The program is evaluated each year using pre- and post-surveys to assess the expectations of the students, their opinions and beliefs about engineering, graduate school and research and their level of satisfaction with different aspects of the program. This provides short-term data on student satisfaction with the program organization, as well as any changes in their opinions and plans immediately upon completion of the program. Yet, one of the most challenging aspects of assessing such a program over the medium to long-term is gathering information about the student participants after they have left the REU program, particularly when most of the participants are from institutions other than OU. Students' contact information changes over time, particularly after they complete their undergraduate degree and move, which can pose challenges for long-term assessment. Using a variety of strategies, the AERIM REU program at Oakland University has been able to continue to gather longer term assessment data on the student outcomes more than 11 years since the inception of the program. The main purpose of

this poster presentation is to share some of these strategies and to report on some of the outcomes and assessment results of the program, particularly as they pertain to the graduate school and career choices of the student participants.

Brief Program Overview

Each summer the students spend 10 weeks working in teams of two or three on their research projects. The teams work closely with the faculty members supervising their projects, graduate students, and one or two industrial mentors. Students also take part in other activities such as industrial research lab and facilities tours, weekly group meetings, meetings with working engineers and automotive researchers, an SAE conference, and seminars. The summer research experience is then capped with students giving oral and/or poster presentations of their research projects both at OU and at research conferences.

Students participating in the REU program receive a stipend, free on-campus housing, as well as a small meal allowance and membership to the campus recreational facilities. Travel expenses to OU are reimbursed and if students get a conference paper accepted, funds are available for them to travel to a conference after the conclusion of the program to present their research. Students and advisers are encouraged to submit their research for publication in conference proceedings or journals and many publications have resulted over the years. More details of past program organization and activities can be found in [2-3].

Student Recruitment and Demographics

One of the first key steps in organizing an REU program is advertising. Over the years, we have found the following to be effective at advertising the program: flyers with information about the program alongside a link to the website were e-mailed and mailed to a number of institutions nationwide and a link to the program website was setup through the NSF REU page. This information was shared with the following people:

- Department heads of mechanical engineering programs via e-mail (through a list-serv of ME dept. chairs)
- Faculty advisors of SAE, SWE, SME and NSBE student groups via e-mail (done by contacting academic liaisons at each of these societies); this was usually the most effective recruiting method.
- Individual faculty members at various institutions
- Advising coordinators at neighboring community colleges
- Past REU participants
- ASEE Women in Engineering Division (WIED) and WEPAN.

The student eligibility requirements were set as undergraduate engineering, science or math students graduating after December; US citizens or permanent residents with a GPA of 3.0 or above. Applications were also accepted from students with slightly lower GPA’s in order to allow for applications from students who might not traditionally apply to this type of program and who might benefit from the experience.

We generally received between 70 and 120 applications each year for the available NSF- funded positions (8 annually between 2006-2008 and 10 annually from 2010-2016). Between 30%-50% of these applications were from female students, one of our key target audiences. The number of applications varied somewhat from year to year depending on how soon we could advertise the program and the starting date set for the 10-week program. Student selection is based on a combination of factors, including GPA, letters of recommendation, personal statement (enthusiasm and effort put into the statement by a student often played a key role), prior research/hands-on experience, geographical location, type of home institution, as well as prior coursework (depending on the projects available for a given year). Prior research, internship or hands-on experience is not a requirement for acceptance into our REU program. This is expressly stated in our REU program announcement as a ways of encouraging students who wouldn't normally consider applying to a research program to apply. In fact, given the impact that such a research experience can have on the motivation, success and persistence of students who may be unsure about engineering, most of the students selected to take part in the program had no prior research experience. When selecting each year's student participants, we always try to select a mix of students that provides a balance between students who have a lot of hands-on experience and students who have none. We also provide project options that include both experimental and computational components to appeal to a range of interests and capabilities. As can be seen from Figure 1, the distribution in terms of college classification varied from year to year depending on the pool of applicants. While in the earlier years most of the participants had completed their sophomore or junior year in college prior to taking part in the program, we have since 2008 been including a larger proportion of students who have just completed their freshman year. Although some faculty mentors were initially somewhat apprehensive about involving freshmen in their research projects (due to their lack of relevant coursework), they inevitably were very impressed by how quickly the students learned and how enthusiastic they were about research. Commenting on one of the recent freshmen who recently took part in the program and who co-authored and presented a conference paper the following spring, a faculty adviser stated that the student *"presented the results of the research at the conference, alongside his teammate, and impressed the audience by his poise, mastery of the material and ability to answer questions from the audience. Most were amazed that he was a sophomore at the time!"*

Although our NSF/DoD grant generally provided funding for eight (in 2006-2008) or ten students (2010-2012 and 2014-2016), on a number of occasions we sought and obtained additional funding from Oakland University's Office of the Provost and Vice President for Academic Affairs**,** as well as from the office of the Vice Provost for Research and from the dean of the School of Engineering and Computer Science to support additional students. In addition, in 2011, two visiting undergraduate students from the Universiti Teknologi MARA, Malaysia joined the REU students in some of the activities and participated in one group's research project. Since the program inception, the GPA's of the student participants have varied between 2.98 and 4.0 with average GPA's between 3.3 and 3.5. The students came from a variety of institutions, including 4-year colleges, colleges with limited graduate programs, and institutions designated by the Carnegie Foundation as being research intensive and extensive universities, as well as a community college. Each year, more than 80% had no prior research or co-

op/internship experience. Hence, this was for most students their first exposure to research and engineering outside of a classroom setting.

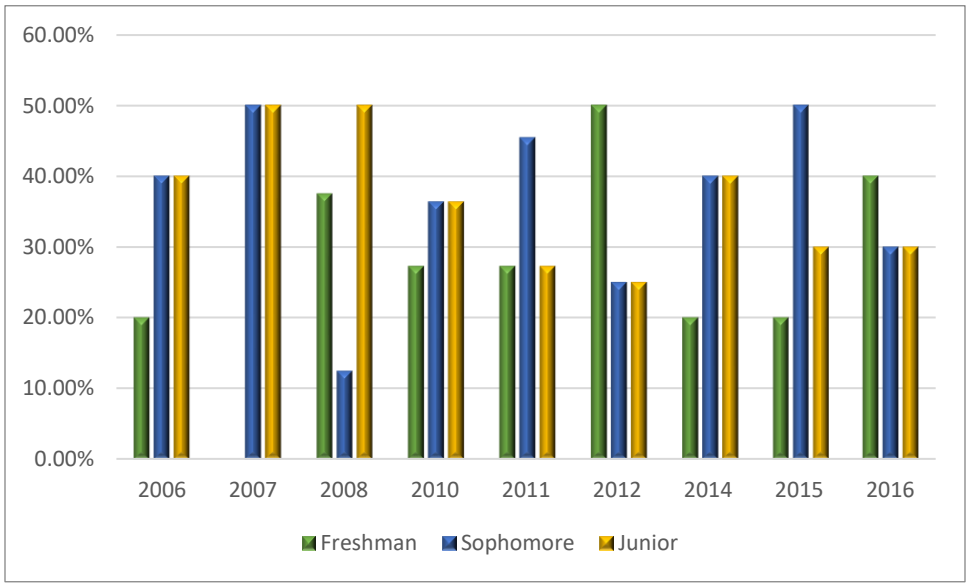

Figure 1: College classification of REU participants

Figure 2 shows the gender distribution for each year that the AERIM REU has been offered. Except for 2010 and 2014 (when it was slightly lower), female students represented 50% or more of the REU participants; in fact, 50% of the 92 participants since 2006 have been female. This represents a much higher percentage than the 20.9% of engineering bachelor's degrees awarded nationwide to women students in 2015-2016 or the even lower percentage of women in the field of mechanical engineering (the primary discipline area of this REU) [12]. This indicates that we were successful at reaching one of our key targeted audiences.

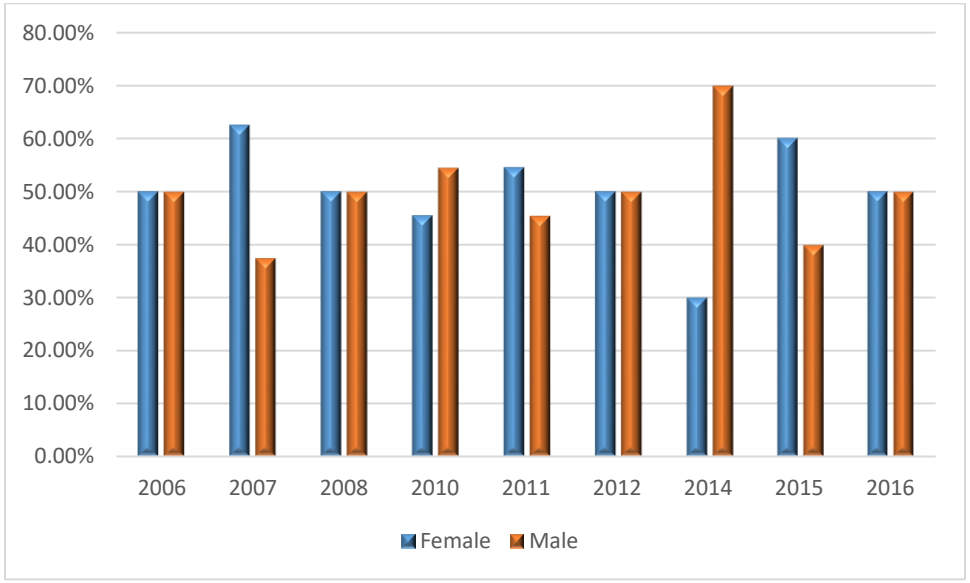

Figure 2: Gender Distribution of REU participants

Figure 3 shows the ethnicity of the participants, as self-reported in their pre-REU survey and application. While the distribution varied somewhat from year to year as it did in the case of college classification, over the nine years that we offered the program, 16.67% of the participants were Hispanic/Latino, 10% were African American, and 12.2% were Asian American, Arab American or other. In some years, up to 33.33% and 20% of the participants were Hispanic/Latino or African American, respectively. These percentages were still higher than the 10.7% of bachelor's of engineering degrees awarded in 2016 to Hispanic students or the 4% to African American students [12]. While our primary focus has been on reaching a wide pool of female applicants, as can be seen in Figure 3, the percentage of Hispanic and African American student participants in our REU program increased after 2011 as we increased our efforts to reach out to these underrepresented groups as well. Noteworthy is the fact that over the life of the program, 70% of all participants were from an under-represented group in engineering (women, Hispanic, African American), as shown in Figure 4. Furthermore, in most years, 40-50% or more of the student participants had parents with no college degree.

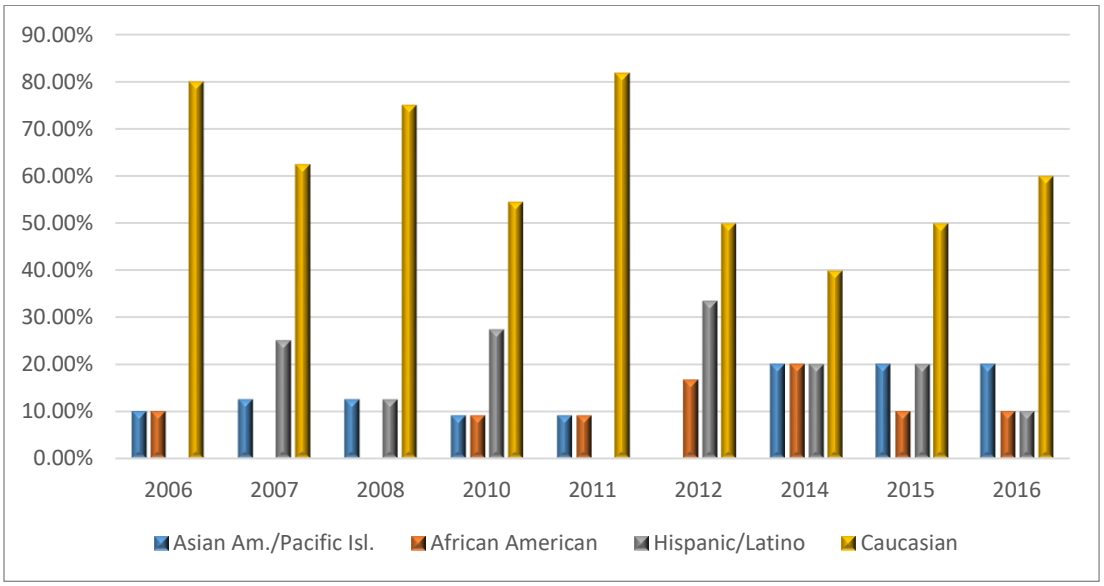

Figure 3: Ethnicity Distribution of REU participants

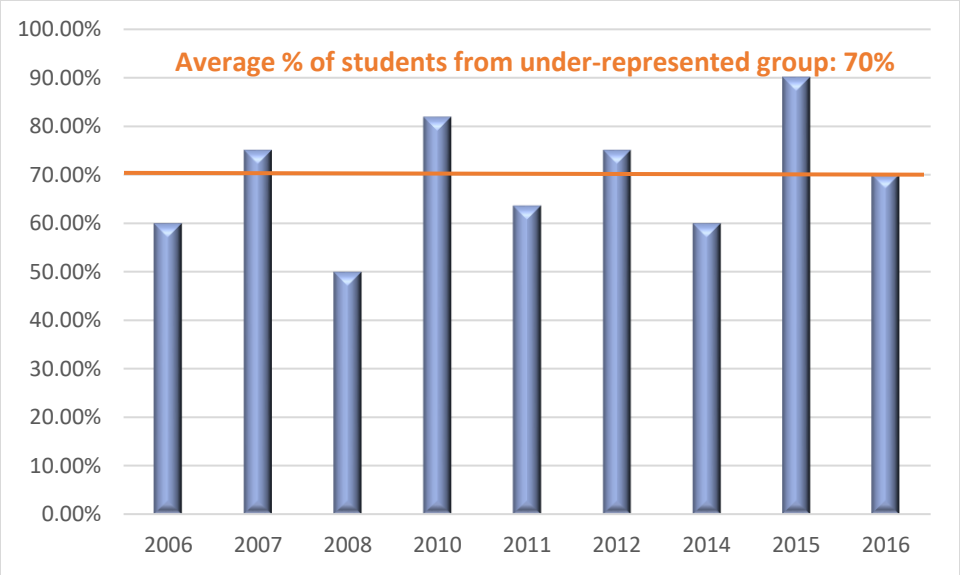

Figure 4: Percent of REU participants from underrepresented groups in engineering (women, Hispanic, African American)

Long Term Assessment of the Program

The REU program was and continues to be evaluated in a number of ways: online pre-REU and post-REU surveys were conducted to assess the expectations of the students, their opinions and beliefs about engineering, graduate school and research and their level of satisfaction with different aspects of the program. This provides short-term data on student satisfaction with the program organization, as well as any changes in their opinions and plans immediately upon completion of the program. Yet, one of the most challenging aspects of assessing an REU over the medium to long-term is finding ways of gathering information about the student participants after they have left the REU program, particularly since most of the participants (in our case, 80% of the 92 participants) were from institutions other than OU. Students' contact information changes over time, particularly after they complete their undergraduate degree and move, which can pose challenges for long-term assessment. In order to follow up on participant progress over time, the AERIM REU program director (grant PI) tries to contact every REU student by phone and/or e-mail at regular intervals of 3-6 months to determine the long term impact of the REU program on the students' professional and educational choices. She also asks the project faculty advisors to forward any updates they may have received from the students to her. In many cases where a student may have moved and not provided new contact information, she has successfully made use of Facebook and LinkedIn to get back in touch with the student. One strategy that has proven beneficial in recent years is to work with students on setting up LinkedIn accounts while they are still at OU taking part in the program, and asking them to connect with the PI. We also ask them for a non-school email address (gmail, yahoo, etc.) to allow for contact in future years. We have however noticed recently that students seem to be using or responding quickly to e-mail less and less, so we are exploring the use of other social media platforms for future years. In fact,

of the 92 students who have participated in the program since 2006, the PI has lost contact with only six (including the two visiting Malaysian students who participated in 2011 in some of the program activities), i.e., less than 5% of the funded U.S.–based students as of February 2018.

On a scale of 1 to 5, with 1 being poor and 5 being excellent, students rated their overall REU experience in the post-REU survey between a 4.4 and a 4.8 (depending on the year) and all indicated that they would recommend the program to their friends. Most of the activities received ratings above a 4.0 and the ratings for categories involving *improvement in skills* (e.g., hands-on and communication skills) and *self-confidence* generally all had average ratings of 4.3 or higher. For example, in 2016, students reported that they learned more about mechanical engineering topics related to automotive and/or energy applications (4.6 rating), developed a sense of how their research contributes to scientific knowledge (4.5 rating), developed a mentor relationship with faculty on whom they can call for guidance in the future (4.3 rating), developed their experimental and analytical skills (4.3 rating), improved their oral communication skills (4.5 rating) and improved their self confidence (4.5 rating). Most of the group activities received high ratings, with the SAE Young Automotive Professionals Conference receiving the highest rating, a 4.8/5 and field trips to industrial or research sites, as well as "Learning more about how to plan for graduate school and careers in mechanical engineering" both receiving ratings of 4.7/5 .

One of the stated goals of the AERIM REU program is to increase the number of students electing to pursue graduate degrees and careers in STEM fields, a key goal of NSF. Not all students from the 2014-2016 cohorts have graduated yet, so we will focus our discussion here on the 2006-2008 and 2010-2012 cohorts. As illustrated in Figure 5, between 10% and 27.3% of the 2006-2008 and 2010-2012 students indicated plans to go to graduate school in the pre-REU surveys; the rest were either undecided or planned on working post-graduation. These percentages increased significantly in the post-REU survey (given on the last day of the program). More significant, however is the fact that of the 60 students who took part in the REU program between 2006 and 2012, between 70% and 90% applied to a graduate degree program and between 60% and 87.5% have either enrolled in or completed one or more graduate degrees. Of the students who have decided not to enroll in graduate school immediately upon graduation, the two main reasons cited are the need to pay down student debt and the desire to gain some work experience prior to going to graduate school. A handful of these students were admitted into prestigious graduate programs, then decided to put their graduate studies on hold to pursue work opportunities at big Tech companies (e.g., Dropbox) or international work opportunities (e.g., BMW in Germany) or entrepreneurship/startups. Others sought PE licensure. Two of the 2006-2008 female students first decided to embark on international work or volunteer experiences upon graduation and have subsequently enrolled in graduate programs in the Netherlands, one at Delft University of Technology, and the other at Technische Universiteit Eindhoven. Others have recently completed their Ph.D. degrees and are working in research capacities. All of the REU participants who have graduated and who are currently working are employed in STEM fields, with many working in the automotive field. One student from the 2012 cohort enrolled in Law school upon graduation and was just offered a job focusing on patent law and intellectual property at one of the biggest law firms in Chicago.

Looking at Figure 5, one can notice a drop-off in the graduate school application and enrollment data after 2010, with the lowest percentages seen in the 2012 cohort. While we are still trying to identify the reasons for this trend, we have a few preliminary explanations for it. First, it has been our experience that the percentage of REU students seeking graduate degrees increases as the number of years post-REU and post-graduation increases. We hence expect to see these numbers tick up again as time goes by. Second, as seen in Figure 1, the percentage of REU participants who had just completed their freshman year when they took part in our program increased between 2010-2012. While research shows that the sooner students get involved with research, the more positive the overall benefit on them, it is also possible that the REU impact on their post-graduation plans diminished as it occurred much earlier in their college career. Third, many students in this cohort started their college studies during the great recession and a larger percentage were from underrepresented minority groups. It is hence possible that they may have been concerned about securing work experience and financial security upon graduation. Further assessment is needed to evaluate this further.

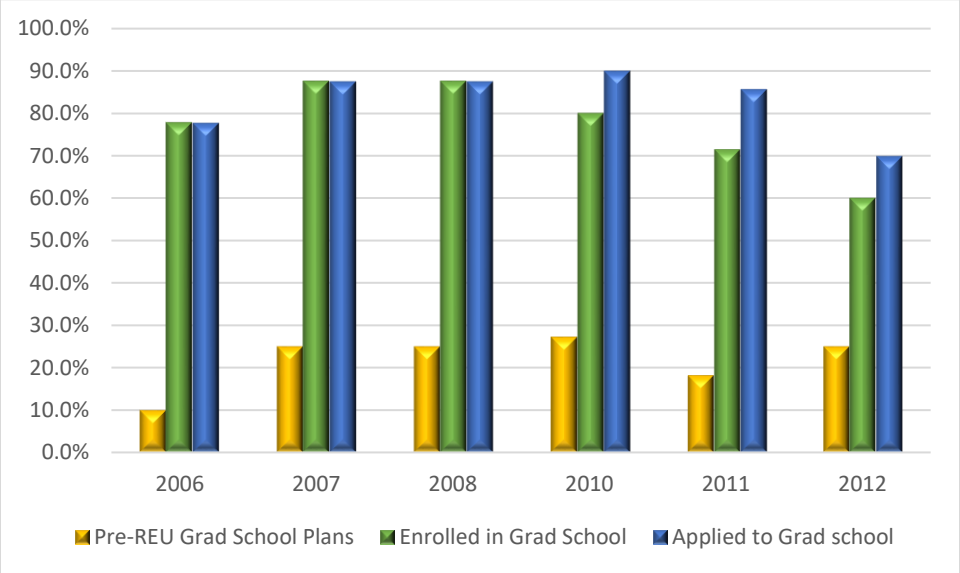

Figure 5: Comparison of pre-REU survey results and actual post-graduation graduate school attainment (2006-2008 and 2010-2012 cohorts); *Applied to Grad School* refers to students who have applied to or are currently applying to Graduate programs.

Overall, given the success our students have had after completing the REU program, whether through employment or through their higher than average percentage of successful graduate school attendance, our REU program's goal of enhancing undergraduates' view of research and increasing their desire for higher levels of learning was fully met. While we obviously cannot attribute all of these outcomes solely to the AERIM REU program, we know based on emails and conversations that we have had with many of the students after they left the program, that their REU experience and the interactions that they had with faculty and industry researchers played a significant role in their decision-making. For example, one of the first students to take part in the AERIM REU program in 2006 recently completed his Ph.D. in biomedical engineering at the University of Southern California. In his Ph.D. dissertation acknowledgment

section, he stated "*I would like to thank Laila Guessous and Brian Sangeorzan for accepting me into the summer NSF Research Experience for Undergraduates at Oakland University during my undergraduate studies. I first became interested in academic research after my great experience there, and I am indebted to them for their generosity in their time and effort mentoring me."* Another female student who took part in the program as a sophomore in 2011 due to her interest in internal combustion engines later enrolled in the mechanical engineering Ph.D. program at the University of Michigan and was awarded an NSF Graduate Research Fellowship. She just recently emailed the PI to inform her of her upcoming Ph.D. defense and went on to state "*The REU really affected my life, and I wouldn't be here without that. In addition, my interactions with you were really inspiring*." Furthermore, the PI just learned a few days ago that a paper co-authored by two of the 2016 REU students was just awarded a student best paper award by SAE. We have over the years received many comments and emails from students indicating that they were offered summer internships, graduate assistantships or full time jobs based on their REU experience. Such feedback from students provides the inspiration for continuing to expand and improve our REU program.

Acknowledgments

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