Tracking Student Participants From A REU Site With NAE Grand Challenges As The Common Theme

Susan Burkett, Ph.D., The University of Alabama, USA
Tabatha Dye, The University of Alabama, USA
Pauline Johnson, Ph.D., The University of Alabama, USA

ABSTRACT

The National Academy of Engineering (NAE) Grand Challenges provides the theme for this NSF-funded Research Experience for Undergraduates (REU) site. Research topics, with their broad societal impact, allow undergraduate students from multiple engineering disciplines and computer science to work together on exciting and critical problems. The approach to addressing the need for research in critical technical areas includes: providing research training in multi-disciplinary research fields; developing technical and professional skills; networking with fellow REU students and participating faculty advisors; and raising student interest and awareness in both graduate studies and our nation's most critical problems. The Grand Challenges investigated by student participants include: making solar energy economical; providing access to clean water; advancing health informatics; securing cyberspace; restoring and improving urban infrastructure; engineering the tools of scientific discovery; engineering better medicines; and advancing personalized learning. Over a three-year period, 34 students participated in the REU Site and 58.8% were students underrepresented in engineering. The student participants published their work and gave presentations in regional and national conferences. Several graduate students gained leadership experience by assisting in program coordination. Based on surveys, overall, student participants value most the opportunity to contribute to a research group on exciting and relevant problems. Tracking efforts resulted in locating 100% of the student participants. We found 38.2% completed their undergraduate degrees and now have positions in industry; 38.2% are currently in graduate school and 8.8% have completed their graduate degrees; 14.7% are still pursuing engineering or computer science undergraduate degrees.

Keywords: Undergraduate; Research Experience; Societal Impact

INTRODUCTION

Undergraduate involvement in research is considered to be one of several high impact practices for enhancing student success (Boyer Commission 2003, Kuh 2008). Positive research experiences are extremely important for raising student awareness of the process that leads to solving complex technical problems. Participants tend to gain a greater understanding of their major discipline, obtain critical thinking skills, improve their communication skills, gain networking opportunities, and have an increased probability of pursuing graduate education (Kardash 2000, Lopatto 2007, Hathaway, Nagda et al. 2002, Russell, Hancock et al. 2007, Carter et al. 2009, Adedokun et al. 2013). Evidence supports that early involvement in research can result in increased retention and GPA when paired to a matched control group (Craney, McKay et al. 2011, Bahr 2009, Cadwell and Crone 2008, Nagda, Gregerman et al. 1998, Schneider, Bickel et al. 2015). Thiry et al. promote undergraduate research as a significant co-curricular activity giving students an understanding of their technical field as well as raising awareness of the type of activities scientists encounter on a daily basis (Thiry et al. 2011). Participation in research experiences can be used to help student cognitive development (Hunter et al. 2006) and is particularly useful when students become involved and are mentored closely in the freshman year and beyond (Stocks et al. 2006).

Undergraduate research has been useful in promoting collaborative interdisciplinary research efforts (Beck et al. 2007, Raicu and Furst 2009), helping to develop core competencies in ethics and communication (Hirsch et al. 2005), involving underrepresented students (Kim et al. 2011), and improving graduate student recruitment (Pariyothorn and Autenrieth 2012). To give students access to research opportunities, NSF has a long-standing program, Research Experience for Undergraduates (REU). For many years, they have funded a large number of (REU) Sites across the nation. We have only seen one other REU Site that tied their theme to a National Academy of Engineering (NAE) report. This was done with a "Back to the Future" theme (West et al. 2011) where skills reported as being critical for success in the NAE Engineer of 2020 were the focus. To raise awareness of the societal impact of research, context was established for engineering projects within the liberal arts. This approach was intended to give students a 'holistic' outlook for viewing their project. Program activities had a heavy focus on technical communications and brought in discussion of diversity and outreach as well. In terms of comparing REU programs, little work has been done in this area. One study did compare an international REU Site in Japan to a domestic REU site and found students from the international Site were indeed more prepared for the global workforce. This would be expected since their program supported activities related to global competence (Ragusa et al. 2014).

The University of Alabama (UA) currently has REU Sites in various disciplines that take place in the summer. We believe one important aspect of providing a research experience to students is to prepare them for conducting research. A few years ago, UA initiated an academic year program, Emerging Scholars, that accommodates a few hundred freshmen each year in all majors with a two-semester commitment. In the first semester, the students attend a seminar preparing them for research and receive assistance in locating a faculty mentor; in the second semester, they work on their research projects. One of the authors has NSF funding to investigate different course formats for preparing STEM students in conducting research (Burkett et al. 2014).

PROJECT OBJECTIVES

The National Academy of Engineering (NAE) Grand Challenges provide a broad and complex set of research problems worthy of investigation; at the same time, this theme provides societal relevance to students. Other educators and researchers have been inspired by these interesting global problems to provide a contextual backdrop for curriculum efforts (Huettel 2011, Chen 2013, Corneal 2014), for outreach to K-12 students and teachers (Talley et al, 2011, Ward and Fontecchio 2012, Fehlinger et al, 2013), and to enhance learning and motivation by building a sense of purpose (Miller et al., 2013, Stolk 2013).

The specific objectives of the UA NAE Grand Challenges REU Site include: training of undergraduates in multi-disciplinary research fields with a common theme; generating student interest in playing a role in a grand challenge with critical societal impact; developing technical and professional skills offering increased future opportunities; networking with fellow REU students and participating faculty advisors; and raising student interest and awareness in graduate studies. The program activities were designed to meet these objectives. NAE Grand Challenges provide the theme and students in multiple engineering and computer science disciplines were supervised by faculty mentors. The Grand Challenges investigated by student participants in this program include: provide access to clean water; secure cyberspace, improve urban infrastructure, make solar energy economical, engineer the tools of scientific discovery, advance personalized learning, and engineer better medicines. Professional development opportunities were provided to the students each year as well as networking and social events.

An example of a research problem studied by a group of REU students majoring in civil engineering and environmental engineering is the NAE Grand Challenge, *providing access to clean water*. This project was part of an EPA grant to investigate the quality of water in a rural area in Alabama. The group of students developed an economical water filter to remove pathogens from drinking water using a combination of sand and granular activated carbon (GAC) treated with iron oxyhydroxide (FeOOH) and/or silver particles. The team of students visited a site where water samples were obtained. They brainstormed ideas with their faculty and graduate student mentor. In their presentation, they described the methods they learned for growing and testing for viruses and bacteria. They created their testing media by using sand and GAC coated with FeOOH and Ag. They performed batch testing of the media and created a filter based on their findings from the tests. One of the students in this group did an internship with a NGO after graduating working on a water supply plan and design of a dam, distribution, and

treatment center for a University in Kenya. This example is shown to illustrate the societal impact of the project and the impact this particular project had on a student's career path.

PROGRAM ELEMENTS

The REU Site project was managed by the PI, co-PI, and a graduate student. The PI was responsible for creating an on-line application, program advertisement, participant recruitment and selection, arranging travel and on-campus housing, and submitting annual reports to the funding agency. The co-PI coordinated all aspects of assessment and assisted with participant recruitment. Each year, a graduate student was responsible for collecting student participant forms (liability, payroll, housing), reminding student participants to complete on-line surveys, arranging speakers, scheduling rooms, and coordinating social events.

The summer program was a nine-week program held each summer from 2010 to 2012 for 10-12 students each year. The session began with a day of orientation and was held jointly with two other REU programs, the REU Site for Software Language Engineering (SLE) and the REU Site for Clean Energy Generation. Each year, an administrator in the College of Engineering and the PIs from each REU Site welcomed the students to the program. The PIs each described their respective REU Site themes and objectives. A team-building exercise was performed in the morning after the student welcome. This activity is based on the popular "Marshmallow Challenge" (see the TED talk by Tom Wujec). Students and mentors were grouped in teams of 4 or 5 and given 20 sticks of spaghetti, 1 yard of tape, 1 yard of string, and 1 marshmallow. The teams are given 18 minutes to build the tallest free-standing structure that would support a marshmallow on top. This activity is a great ice-breaker and helps students and mentors (both faculty and graduate students) get to know each other. After this activity, mentors took the student participants to their offices to describe their research projects ending with a tour of the facilities. After a common lunch, a staff member from UA Student services conducted a tour of the campus highlighting historical buildings, libraries, the student recreation center, and dormitories.

After the first day, students started working with their faculty and graduate student mentor after any relevant safety or equipment training was completed. Each week, the students in the REU NAE Grand Challenges Site had a common meeting for 1 ½ hours. In the 9-week program, 7 guest speakers were invited to give talks with either a technical or professional development focus. The students gave presentations in 2 of the weekly meetings. Midway through the summer program, students gave a presentation using a quad-chart format. This format enabled quick presentations by the students. Students were given a template for the quad chart to help guide their presentations. Each of the four quadrants contained the following information: student name and name of the Grand Challenge; schematic, graphic or image; objectives; and key findings to date. The final meeting of the summer was a joint poster session held with the REU – SLE Site participants. Students prepared a poster showing the methods and findings of their research experience at the University of Alabama.

Because so many of the NAE Grand Challenges are related to sustainability, guest speakers were chosen with this focus; other speakers were chosen based on their ability to build the skills of the participants. A typical set of seminar topics included: transportation/urban infrastructure, alternative energy, water quality, effective use of library resources, writing an abstract, academic resumes, and the graduate school application process. Each summer, students participated in social events that were chosen based on their interests. Some of the most popular activities included: a tour of the local Mercedes Benz factory, the Moundville Archaeological Park (a site in central Alabama that was occupied from around 1000 until 1450 A.D.), the Civil Rights Institute in Birmingham, movie and game nights, and a picnic at Lake Lurleen State Park. Table 1 shows a typical summer schedule for REU students.

Table 1. Timeline for REU Student Activities

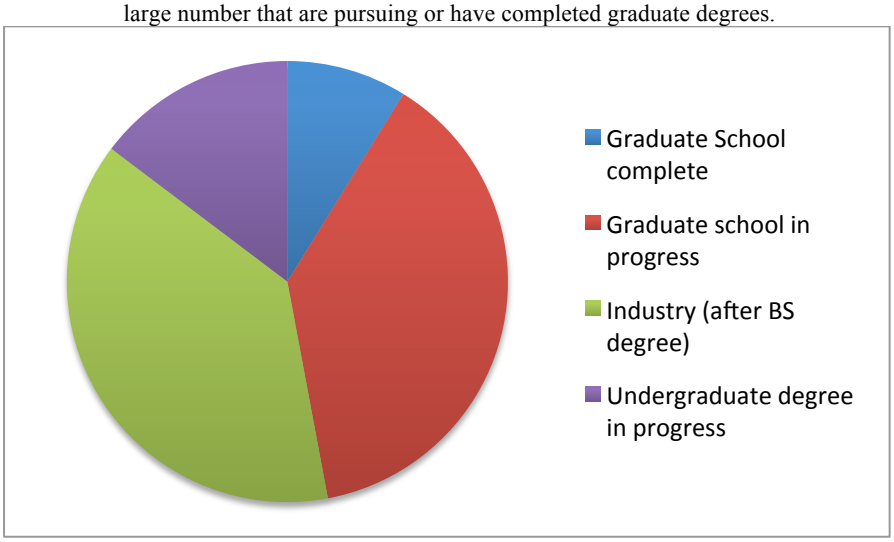
Time	Activity
Week 1, Day 1	Orientation: Breakfast, Welcome by the Dean, team building activity, meet with mentors, lunch, campus tour.
Week 1, Day 2	Safety training appropriate for laboratory (e.g., chemical hygiene, chemical waste disposal, radiation, etc.)
Week 1, Day 4	Speaker: Transportation/Urban Infrastructure – Prof. Stephen Jones Social/Cultural: Moundville Archaeological Park Visit
Week 2	Quick report from students on progress Speaker: Library Resources – Prof. Susan Burkett
Week 3	Speaker: Alternative Energy for a Sustainable Future – Prof. Clark Midkiff
Week 4	Speaker: Writing an Abstract – Dr. Luke Niiler, UA Writing Center
Week 5	Quad Chart Presentations by Students, Professional Development: Mercedes Benz Tour
Week 6	Speaker: Effective Presentations – Prof. John Baker Social/Cultural: Civil Rights Institute
Week 7	Speaker: Water Quality – Prof. Joe Brown
Week 8	Speaker: Preparing for Graduate School – Prof. Andy Goodliffe, UA Graduate School Social: Lake Lurleen State Park picnic
Week 9	End of summer poster session

PARTICIPANT DEMOGRAPHICS AND TRACKING EFFORTS

Our project team focused recruiting efforts on students from various universities around the country and some of our own students from the University of Alabama (UA). All students were selected from the applicant pool. Program deadlines were in early March with offers made to students in late March or early April. Students applied on-line (http://reu.eng.ua.edu). In the three-year summer program and no-cost extension year, 34 students were mentored by faculty in seven degree programs: chemical, civil, environmental, mechanical, electrical/computer, metallurgical & materials engineering, and computer science. There were 20 participants (58.8%) underrepresented in engineering and computer science (47% female, 14.7% African American, 2.9% Hispanic, and 2.9% Native American). Our goal was inclusion of 50% underrepresented students in each summer cohort and we met that stated goal each year.

An important part of our recent activity was to track our REU participants three years after the last cohort completed the program. A combination of Facebook, LinkedIn, and faculty advisor communications helped us locate all 34 students (100%). Tracking efforts indicate that 38.2% completed their undergraduate degrees and now have positions in industry while 14.7% are still pursuing engineering or computer science undergraduate degrees. In addition, 38.2% are currently in graduate school while 8.8% have completed their graduate degrees. Almost half (47%) of our students have received or are pursuing graduate degrees. The distribution is provided pictorially below.

Figure 1. Pie chart illustrating distribution of REU students highlighting the large number that are pursuing or have completed graduate degrees.



In terms of dissemination, several papers have been published and oral presentations or posters were presented in regional and national conferences. One student received 2nd place in an IEEE SoutheastCon Ethics Competition, one student gave a talk at the University Transportation Center for Alabama meeting, one student poster, "Better Bamboo Bikes: Mechanical Properties of Alabama-Grown Bamboo," received second place for best poster at the UA Women in Science and Engineering (WiSE) conference held in 2013. Ten journal articles have been published. Students rate the quality of the program high (mean of 4.3 on a 5.0 scale) and 100% would recommend the program to others. They noted increased confidence, especially in giving presentations, as a significant benefit of participating in the program.

ASSESSMENT

Project evaluation served as a source of ongoing information to aid in continuous program improvement and as a measure of the extent of student learning and the attainment of program objectives. The primary assessment tool, from which the qualitative and quantitative evaluation framework was constructed, was an online survey modeled on the NSF's *User-Friendly Handbook for Project Evaluation* (NSF 2002). Furthermore, prior to commencing the study, the UA Institutional Review Board (IRB) reviewed and approved the project protocol to ensure the evaluation methodology was culturally responsive.

Formative evaluation was used to assess ongoing project activities. The evaluations helped to provide information for monitoring and improving the project and to assist in evaluating our progress towards meeting goals. Bi-weekly feedback was gathered to afford the opportunity for intervention as any problems arose. The entire project team reviewed evaluation summaries and made subsequent adjustments to the program as necessary. Summative evaluation assessed the quality and overall impact of the project.

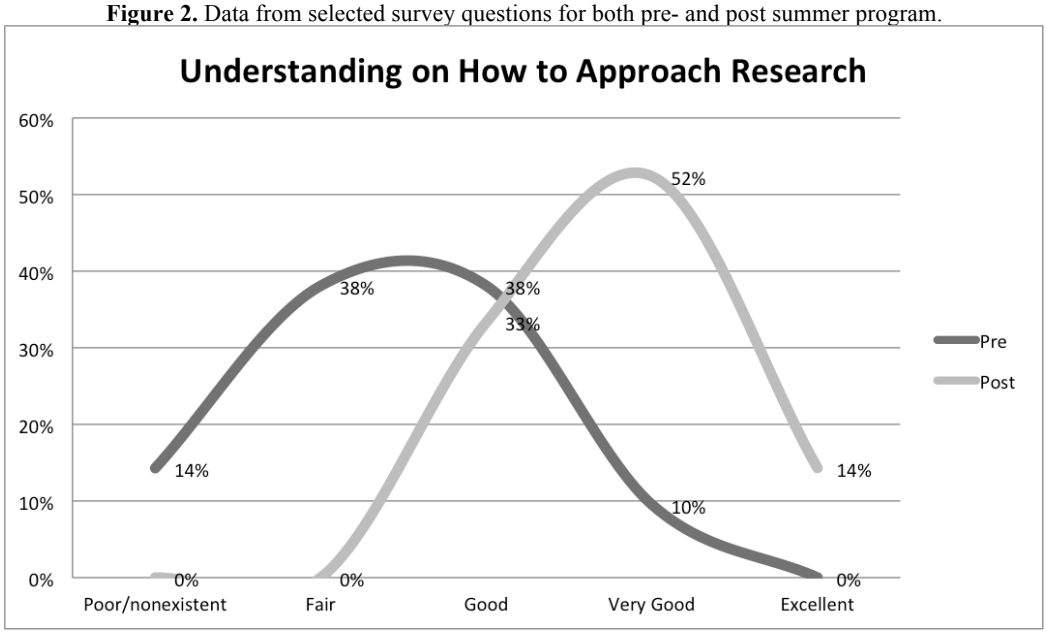
Assessment activities involved four main areas: demographic data collection; pre-project, bi-weekly and end-of-project student surveys; annual follow-up student surveys; and outcomes data including things like conference presentations, journal publications, and any changes or insight into future career paths.

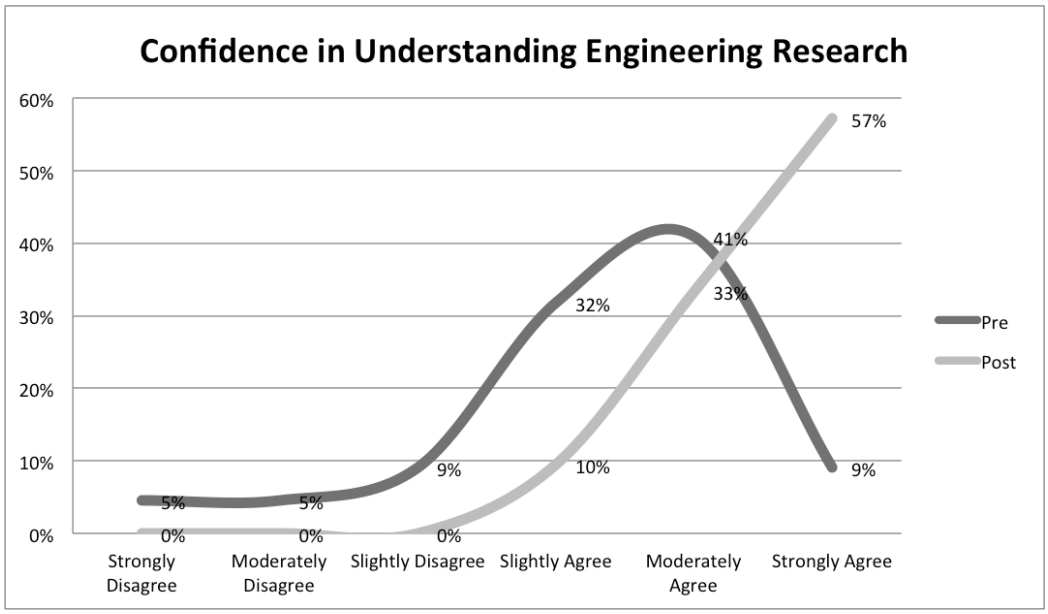
By using the paired t-test, questions were compared before and after the program to determine program effects. Questions were determined to be statistically different at a p-value of 0.05 or less. Participants include students who participated in the pre and post survey for the three program years (n=22 out of 34 students).

Overall, students rate the quality of the program high (mean of 4.3 on a 5.0 scale) and 100% would recommend the program to others. They noted increased confidence, especially in giving presentations, as a

significant benefit of participating in the program. Data from selected survey questions are highlighted in Fig. 2. Participants felt more interested in, and better understood, how to approach scientific or engineering research. This is an important finding as we focus on preparatory skills in our professional development opportunities. Participants gained knowledge of the Engineering Grand Challenges. We consider this finding important as well since one of our goals was to raise student awareness of the NAE Grand Challenges. More specifically, participants improved confidence in their ability to understand engineering research, develop research questions, do engineering research, design a research study, contribute to discussion on their findings, evaluate the quality of a research study, and present research findings. Participants who expected the program to be challenging did not find the program to be so. We are encouraged they did not feel overwhelmed and felt prepared. One area they would have liked more help with is interpreting research findings. This is an area the faculty mentor could focus on in the future. Overall, participants felt that the program would indeed influence their career path.

Figure 2. Data from selected survey questions for both pre- and post summer program.





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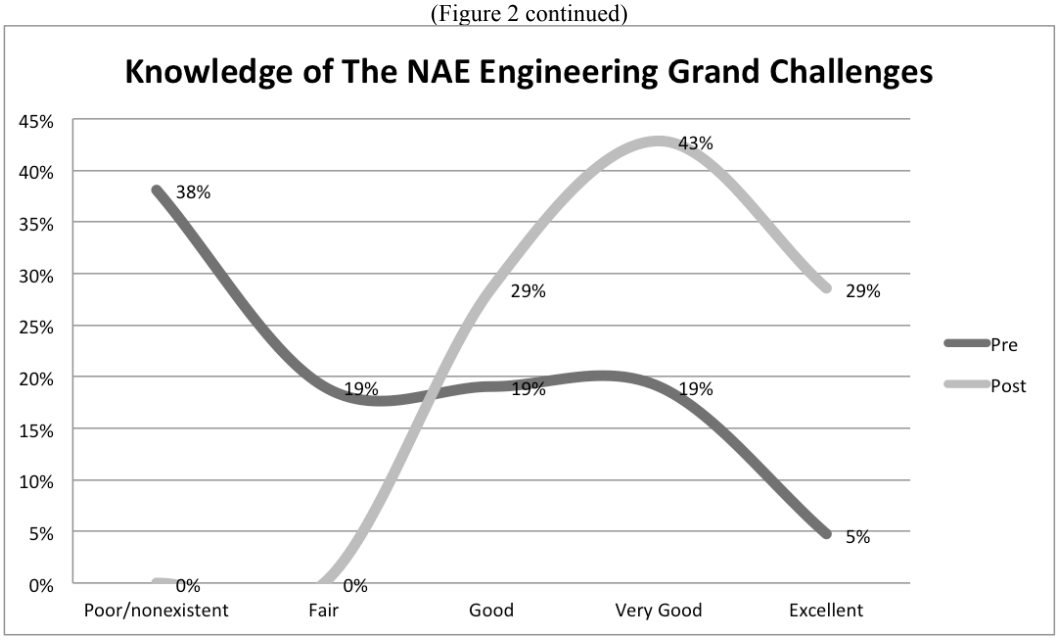

Other pre- and post-program questions were not significantly different; this implies that their expectations of the program were met. Participants maintained confidence in their ability to develop technical research skills, evaluate results of a research study, and to write-up research for publication. Participants both expected and experienced the program to be enjoyable, give insight to emerging areas of research and challenges in engineering, and provide the chance to get paid to work on something related to their interests. Participants likelihood of pursuing further undergraduate research opportunities, find graduate school attractive, go to graduate school specifically in science or engineering, and pursue a professional career in research were the same before and after the program. The program did not change the participants' perception of research and graduate school; most students already found graduate school attractive and planned on attending graduate school in general or in science/engineering. This conclusion is likely due to the fact that students interested in research or graduate school have shown their interest by applying for this REU program during their undergraduate years.

These selected quotes from the survey provide a qualitative data aspect. "The program gave me a very sound understanding of what research is like, including the broad goals and the every day activities. This was very useful to me, as I have never done any research before. The set up allowed me to gain the full experience, but also gave me a safety net. If I did not like the experience and the research lifestyle, I only had committed myself to 9 weeks. On the other hand, if I did enjoy it, it gave me knowledge on how to approach research in my university or my city. It also opened doors for my future, maybe next summer." "I would very much recommend this program to others. It is a great introduction to the research side of engineering. The program introduced me to students and faculty I may have never met otherwise and gave me a sense of purpose and belonging in the engineering field." "I have begun to consider graduate school as a serious possibility [*sic*] in the future. I hope to earn an REU position at another institution next summer in order to gain even more experience."

Based on surveys, student participants value most the opportunity to contribute to a research group advancing knowledge of an exciting and relevant problem. The Grand Challenges have provided an excellent opportunity to enhance the research experience. Other feedback, determined from assessment, is that students indicate they gained valuable experience in preparing for and giving oral and poster presentations.

Outcomes from the program according to the students included improved knowledge in engineering research methods, knowledge of NAE Grand Challenges, interest in continuing research, and likeliness to go to graduate school. A challenge identified by students was a lack of social interactions as students were assigned individually to faculty research programs. In the future, ensuring that students are paired when working on a research project could help solve this challenge.

CONCLUSIONS

After three years, 34 students participated in this multi-disciplinary site where students worked on research problems identified by the NAE as our nation's *Grand Challenges*. The potential benefits of this site are training students in multi-disciplinary fields with awareness and interest in problems with societal impact. The program was 9-weeks in length and included seminars, professional development opportunities, and social events in addition to the mentored research experience. Tracking efforts show most students completed their degrees and are either employed in industry or are pursuing engineering or computer science graduate degrees. Previous student participants are currently attending graduate schools, or completed graduate degrees, at UA, U Florida, Michigan Tech, Colorado School of Mines, Louisiana State, Louisiana Tech, Penn State, South Dakota School of Mines and Technology, and U Tennessee. Overall, 58.8% of the student participants were from underrepresented groups. Research results were disseminated in peer-reviewed journals and in regional and national conferences. Students rate the quality of the program high (mean of 4.3 on a 5.0 scale) and 100% would recommend the program to others. They noted increased confidence, especially in giving presentations, as a significant benefit of participating in the program.

AUTHOR INFORMATION

Susan Burkett is the Alabama Power Foundation Endowed Professor in Electrical and Computer Engineering at The University of Alabama. She received her B.S., M.S., and Ph.D. degrees in Electrical Engineering from the University of Missouri in Columbia, Missouri. She teaches courses in circuit analysis, integrated circuit fabrication, and senior design. She served as Program Director at the National Science Foundation (NSF) in the Division of Undergraduate (DUE) Education from 2005-2007. Professor Burkett is a member of ASEE, AVS: Science and Technology Society, and a senior member of IEEE.

Tabatha Dye is a Ph.D. candidate at the University of Alabama Department of Civil, Construction and Environmental Engineering specializing in water quality. She also serves as a graduate research assistant for the Capstone College of Nursing. She received her B.S. and M.S. from The University of Alabama. She has assisted in REU program assessment.

Pauline Johnson is a Professor in the department of Civil, Construction and Environmental Engineering at The University of Alabama (UA). She received her BS degree from Salford University Manchester, Postgraduate Teaching Credential from St Andrews College in Scotland, and PhD degree from The Queens University Belfast, N. Ireland. She teaches courses in water and wastewater treatment design, resources management, and introduction to environmental engineering. She serves on the UA executive committee for community based partnerships and is faculty adviser for Student Engineers in Action. She is a member of ASCE-EWRI.

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