HUMAN RESOURCES

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Continuing efforts

Research Experiences for Undergraduates (REU)

In 1958, NSF established the Undergraduate Research Participation (URP) program to encourage the development of undergraduates into independent research investigators. The program was highly successful and provided support for a substantial number of talented undergraduates. Participants in the program were juniors or seniors from the institution receiving a URP program grant. Although the URP program ended in 1979, the importance of undergraduate involvement in research was not dismissed.

In 1986, the Research Experiences for Undergraduates (REU) program was established across the NSF, with both site and supplement grants awarded in 1987. The primary differences between the earlier URP and the present REU programs are: (1) the URP program did not emphasize the importance of recruiting underrepresented students and (2) it accepted participants primarily from the institution receiving the URP grant. The REU program emphasizes the importance of involving underrepresented groups (women, minorities and persons with disabilities) and requires that a significant number of the student participants come from outside the host institution or organization.

The REU program is a major contributor to the NSF goal of developing a diverse, internationally competitive, and globally engaged science and engineering workforce. The REU program is considered one of the most effective avenues for attracting talented undergraduates to and retaining them in careers in science and engineering, including careers in teaching and education research.

The REU program goals are to: (1) expand student participation in all kinds of research—whether disciplinary, interdisciplinary or educational—encompassing efforts by individual investigators, groups, centers, national facilities and others; (2) help develop a diverse, internationally competitive, and globally engaged scientific and engineering workforce; (3) promote the integration of research and education; and (4) encourage faculty to seek talented students traditionally not included in research activities. The program aims to develop undergraduates into independent researchers, rather than dependent learners. Whereas the typical academic experience separates education and research, the REU program provides a research opportunity for undergraduates, a value-added component of their formal undergraduate education.

The REU program objectives are achieved by providing research experiences for undergraduates through two funding mechanisms: REU sites and REU supplements. REU sites are based on independent proposals, submitted at an annual deadline, to initiate and conduct projects that engage a number of undergraduates in research. The sites must have a well-defined common focus that enables a cohort experience for students. Currently there are more than 100 active ENG/REU sites, each with a group of 10 or more undergraduates who work with faculty and graduate mentors on carefully defined projects aligned with the research programs of the host institution.

REU supplement programs may be included in proposals for new or renewal ENG grants or as supplements to ongoing ENG-funded projects. REU supplements generally provide support for a small number of students (usually one or two), and are limited to a maximum of $6,000 per student for one year, with the exception of REU supplements for ERCs, which include usually five or more students.

In 2002, NSF's Division of Research, Evaluation and Communication (REC) commissioned a nationwide study, *Undergraduate Research Opportunities* (URO), to examine all NSF mechanisms supporting undergraduate research, including REU sites and supplements. It covered a wide range of NSF programs and directorates, but did not obtain detailed information about any one.

ENG aims to obtain in-depth information about the activities, outcomes and impacts of its REU sites and supplements programs from the perspectives of the former REU students, principal investigators (PIs) and other faculty mentors. In November 2006, ENG contracted SRI International to conduct a study of the REU programs in order to compare REU sites funded by EEC, REU supplements funded by the ERC program (ERC Supplements) and REU supplements funded by other ENG divisions. The study will also assess differences among respondent groups (undergraduates, PIs, other faculty mentors). Among undergraduates it will assess differences by gender, race and ethnicity, and total duration of the undergraduate research experiences.

The study will begin with a survey of faculty and undergraduate participants in ENG REU programs and be followed two years later with a survey of undergraduate participants.

It is anticipated that the study results will help NSF better understand the components and characteristics of effective REU sites and supplements and will help provide direction to the ENG program directors in management and oversight and in determining the future direction of the programs. Results from the initial surveys are expected in October 2007 and the final follow-up survey results are expected in September 2009.

Research Experiences for Teachers (RET)

Encouraging active participation of K–12 teachers in NSF projects is an excellent way to reach broadly into the U.S. teacher talent pool and to encourage more K–12 students to pursue engineering studies by increasing their understanding of engineering, as conveyed by their teachers. In order to pursue this goal, ENG initiated the Research Experiences for Teachers (RET) program in fiscal year 2001 as a pilot effort intended to bring knowledge of engineering and technological innovation to the precollege classroom.

In its first year, the program provided support for supplements to ongoing NSF/ENG projects and to groups of K–12 in-service and pre-service teachers at nine ERCs. This successful pilot effort within these ERCs was the catalyst for launching the annual ENG-wide RET site competition in fiscal year 2002.

In fiscal year 2003 the program was further expanded to include and encourage the participation of community college faculty in ongoing research and education activities funded by ENG. To date, as a result of the five annual ENG/RET site competitions, 32 RET site awards have been funded and approximately 500 K–12 teachers and community college faculty participate in these programs each year.

The RET program aims to build long-term collaborations among in-service and pre-service K–12 teachers, community college faculty and the engineering research community in institutions of higher learning. RET also aims to support the active participation of these teachers and future teachers in research and education projects funded by NSF/ENG, to facilitate professional development of K–12 teachers and community college faculty through strengthened partnerships between institutions of higher education and local school districts, and to encourage researchers to build mutually rewarding partnerships with teachers.

The RET program achieves its objectives by building partnerships between teachers and engineering researchers through two funding mechanisms: RET supplements and RET sites. RET supplements may be included in proposals for new or renewal ENG grants or as supplements to ongoing ENG-funded projects and are limited to a maximum of $10,000 per teacher for one year. RET sites are based on independent proposals to initiate and conduct research participation projects on campuses for a number of K–12 teachers and/or community college faculty. RET sites are limited to a total maximum of $500,000 for a duration of up to three years.

ENG strongly encourages all of its grantees, including grantees from the Small Business Innovation Research (SBIR) and the Small Business Technology Research (STTR) programs, to identify talented teachers for participation in the RET sites. ENG also strongly encourages the use of RET supplements and sites to enable K–12 teachers of science, mathematics and engineering, as well as community college faculty, to participate in ongoing REU programs.

In 2003, NSF contracted with SRI International to **evaluate the ENG RET program** (see http://www.sri.com/policy/csted/reports/university/index.html#ret2006.) The primary objective of this evaluation was to understand how the RET experiences of ENG RET participants affected their teaching techniques, attitudes about teaching and professional development activities. Also examined were outcomes and impacts beyond the teachers' classrooms, such as knowledge transfer activities or formal partnerships formed between the RET PI and the teacher's school system/district. The study did not assess the impacts of RET on students, other than through participants' reports.

The evaluation found that a majority of the 2001–2005 ENG RET participants were enthusiastic about their participation. Almost all reported that they had received a variety of personal and professional benefits from the program, including new enthusiasm for their teaching; new teaching strategies; a greater awareness of research methods, issues and career opportunities; and enhanced professional opportunities. Moreover, the majority said that their students also had benefited, most often through increased enthusiasm for science, technology, engineering and mathematics subjects and increased awareness of science, technology, engineering and mathematics careers.

The RET program solicitation has been revised, strengthened and improved based on feedback received from survey participants, recommendations received from the academic community, NSF ENG staff and others interested and involved in the RET program. Specifically, RET site programs funded in fiscal year 2007 and beyond will require a strengthened and substantive follow-up plan between the university participants and the teachers and their students throughout the academic year to ensure classroom implementation of curricula and other materials developed during the summer experience. This addition grew out of suggestions RET participants made during the SRI International survey of the RET program (see above).

The on-campus program for teachers will last at least six weeks during the summer and PIs will be strongly encouraged to select teams of teachers (at least two teachers per school) from underrepresented school districts to maximize the impact of the RET project. The total funding request level for an RET site program has been increased to a total of $500,000 over three years. It is anticipated that five RET site awards will be funded in fiscal year 2007, based on an estimated available budget of $3 million.

A supplemental funding opportunity for the support of RET sites within ENG's Center and Network programs will be offered under the annual RET program solicitation. The Centers/Networks include all ongoing ERCs, the Nanoscale Science and Engineering Centers (NSECs), the NNIN and the NCN.

NIBIB-NSF Bioengineering and Bioinformatics Summer Institutes (BBSI)

The creation of the National Institute of Biomedical Imaging and Bioengineering (NIBIB) within the National Institutes of Health (NIH) in 2001 signaled recognition of the importance of bioengineering and the emerging field of bioinformatics to the nation. Soon afterward, in fiscal year 2002, NSF and NIBIB established a jointly funded and administered program, NIBIB-NSF Bioengineering and Bioinformatics Summer Institutes (BBSI), aimed at beginning to create a supply of professionals trained in bioengineering and bioinformatics.

NSF and NIBIB/NIH identified bioengineering and bioinformatics as essential interdisciplinary disciplines for physical and life sciences and these two areas are considered in their broadest sense. Examples include: tissue engineering, biomaterials, drug delivery systems, implant sciences, biosensors, platform technology development, computational modeling, algorithm development, medical imaging, and image analysis. New areas that would benefit from the significant value added of applying the technologies and methods of bioengineering and bioinformatics include the dynamics of complex physical and/or chemical systems, biomimetic systems, systems that demonstrate emergent behavior, genomics, systems biology, biodiversity and ecology.

To date, as a result of two BBSI competitions, 22 BBSI awards to 13 universities have been funded through the support of NIBIB/NIH and five NSF directorates—ENG, MPS, CISE, Biological Sciences (BIO), and EHR. NIBIB and NSF support the program equally ($1.5 million total per year—$750,000 from NIBIB and $750,000 from NSF); but the BBSI program is managed within EEC.

The purpose of the BBSI program is to provide undergraduate and early-stage graduate students majoring in the biological sciences, computer sciences, engineering, mathematics, and physical sciences with well-planned, interdisciplinary bioengineering or bioinformatics research and education experiences in active Summer Institutes, thereby increasing the number of individuals pursuing careers in bioengineering and bioinformatics at the graduate level and beyond. NSF and NIBIB/NIH are collaborating on an important effort to meet anticipated bioengineering and bioinformatics human resource needs, specifically by targeting the career pipeline at a critical juncture.

Each BBSI award includes about 15 undergraduate and graduate students and receives joint NIBIB-NSF support of up to $200,000 (total cost) per year for up to four years. There have been two program solicitations since the program was established in fiscal year 2002. The first solicitation resulted in nine summer institutes being awarded nine four-year programs that began in 2003. All nine of those programs received renewed funding in fiscal year 2006 for additional three-year programs.

New initiatives

Partnerships in Pathways to Engineering

Today, less than 7 percent of all students entering four-year colleges are choosing to study engineering, compared to 10 percent of students two decades ago. Engineering enrollment has maintained a reasonably constant level in absolute numbers over this time period, relying simply on the steady increase in the number of high school graduates. But the number of high school graduates will begin to decline in 2010 and, if trends in student interest in engineering remain constant, an absolute decrease will occur. What is needed is a change in how middle and high school students come to know (or not) about engineering.

Interest in the K–12 pipeline into engineering fields is not a new concern. Business and government have invested substantial resources in the study and improvement of this pipeline for some time. The NAE's *Rising Above the Gathering Storm* and the president's *American Competitiveness Initiative* both address this pipeline as a critical national resource. It is also an EEC priority. One example is the RET program, discussed above, which supports about 500 teachers annually. These teachers impact the thinking of many students. But with an estimated 250,000 math and science teachers nationwide, the RET program is difficult to scale adequately.

However, some programs operated by non-profit organizations do scale well. Most programs are either curricular or extra-curricular. As the names suggest, curricular programs are directed at the school curriculum itself, while extra-curricular programs focus on after-school activities. Three programs deserve mention.

Project Lead the Way began in 1997 with 12 high schools in New York state. These high schools adopted and implemented curricular material relating to topics in engineering such as digital electronics, computer-integrated manufacturing and engineering design. Today, Project Lead the Way is in place in 1,300 schools in 45 states. In some cases, the program has helped students gain college scholarships and enroll in engineering programs. These students may not have been able to attend college otherwise ("Engineering Program Builds Road to College," *Washington Post*, June 3, 2007).

Another successful curricular project is Retirees Enhancing Science Education through Experiments and Demonstration (RESEED). This project, which began in 1991 and is centered in New England, recruits and trains retired engineers to assist science teachers in middle schools. Seventy-five percent of all teachers of physical science for the seventh and eighth grades do not have degrees in the physical sciences!

Entrepreneur Dean Kamen started the FIRST Robotics Program in 1992 with eight high schools in New Hampshire. Teams of high school students, with industry mentors, build human-sized robots with the capability to move, transport and deposit items like balls and cartons into goals, setting the stage for competitions. Today, nearly 1,500 high schools

maintain teams and nearly 20,000 seniors per year graduate with real experience in the engineering sequence of design, build and test as a member of a real team.

The question is: Are programs like these contributing to the engineering pipeline? Some impact is obvious. But do a larger percent of FIRST and Project Lead the Way students matriculate into engineering programs? Are they retained at a higher rate than other students with little connection to engineering? Do they become the real leaders and innovators?

Another systematic opportunity that will be investigated is the relationship between the leaders of engineering schools (deans) and those of K–12 school districts (superintendents and principals). Past and present NSF programs have focused on connecting the operating personnel of the two institutions, namely professors and high school and middle school teachers. Programs like RET and Graduate Teaching Fellows in K–12 Education (GK–12) represent such partnerships.

However, unlike formal partnerships between engineering schools and industry (Industry Advisory Boards), no similar partnerships exist between superintendents and principals and engineering deans. It is important to understand what barriers are inhibiting such partnerships. Do the leaders of a given school district know where their students are headed after graduation and do they have reasons to care?

EEC proposes a program that will seek answers about the impact of these programs on the engineering pipeline. It is anticipated that several schools might be supported to partner with these organizations to help collect and analyze demographics as well as the longitudinal impact on students' career choices and their retention in and graduation from engineering programs.

Catalyze the Plan for a Pre-AP in Engineering

Historically, the College Board has offered a broad range of courses and national standardized tests designed for high school students to demonstrate the necessary proficiency to gain placement in advanced college courses. However, students seeking to gain advanced placement in engineering introductory college-level courses are not provided the same opportunity offered to those in the sciences, mathematics and other disciplines. That is to say, there is no AP Engineering test to fuel creation of an AP engineering course.

Over the past 24 months, ENG has provided funds to research the feasibility and the practicality of a Pre-Advanced Placement (AP) model for engineering. A Pre-AP in engineering would be offered to ninth and tenth graders and potentially pave the way for a AP engineering course. This research effort has involved the interviewing of teachers, engineering faculty, educators and experts from industry, trade associations and funding organizations. The research encompassed eight focus groups around the United States

involving more than 100 people, more than 20 expert interviews, and a pilot study involving 155 students at nine sites on the East and West coasts.

In order to gain feedback on the results of the research, presentations have been made to organizations like the College Board, the American Society of Mechanical Engineers and the American Society of Civil Engineers. The College Board responded by issuing a statement in early February of 2007 saying it "applauds … the National Science Foundation for funding and conducting the research." In particular, the College Board accepted the study's finding that a pre-AP engineering course would prepare students to enter into an engineering course of study.

In a statement entitled "Engineering Programs in U.S. Secondary Schools," the College Board wrote that they "would be eager to explore what work could be done to build the sort of high school engineering programs that would prepare students for college-level engineering courses." Therefore, the College Board staff was prepared to work with the research team to explore the possibility of a first-time-ever pre-AP course of study—for any disciplinary subject! The pre-AP most likely will reach a much more demographically diverse audience of students, including not only those interested in exploring engineering, but also those who are curious to learn about the design process through the practice of mathematics and science concepts.

The engineering community can provide leadership to develop a course of study or process for a pre-AP that could eventually be replicated and thereby impact STEM education across the United States.