

The value of undergraduate research

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ABSTRACT: In recent years, a relative decline in the interest and aptitude of American students in engineering and other technical fields has been observed. As such, the USA has identified the need for academic institutions to develop and implement innovative curricula that cultivate student interest in an aptitude for careers in engineering/technology and engineering research. One such programme that has gained momentum is the Research Experiences for Undergraduates (REU) programme funded by the National Science Foundation. Rowan University has been hosting REU since 2001. The central unifying theme for the Rowan REU is *Pollution Prevention and Sustainability*. Undergraduate engineering and science students work on REU research projects that involve them in ongoing research programmes to promote interest in their careers and graduate school. This eight-week programme exposes students not only to the values of research experiences, but also helps them to strengthen their communication, social, teambuilding and leadership skills. The ultimate objective is to provide REU participants with an enriching research experience to encourage them to pursue graduate studies. This will allow native students to contribute to the technological innovation and expertise required for the nation's success and prosperity.

INTRODUCTION

US leadership in technology is a top priority for the nation. Challenges facing this leadership include the rapid rate of discovery and the development of new technology, more competitive research and development investments by other countries, and the education of a competitive technical workforce. In recent years, a decline in the interest and aptitude of American students in engineering and technical fields has emerged. As such, the nation is funding numerous K-12 and college initiatives to promote students' interest in science and engineering. It is imperative that the USA focus on the development of a technical competent workforce that can contribute to fundamental and applied engineering research to continue its leadership in innovation in the global market.

The National Science Foundation (NSF) introduced the Research Experiences for Undergraduates (REU) programme many years ago. The major objective of this programme is to provide undergraduates with enriching research experiences that promotes the will to pursue graduate education. REU opportunities are an excellent way to reach broadly into the student talent pool of the nation [1]. The NSF is particularly interested in increasing the participation in research of women, underrepresented minorities and persons with disabilities. REU projects are strongly encouraged to involve students who are members of these groups. Underrepresented minorities are African Americans, Hispanics, American Indians, Alaska Natives, and Native Hawaiians or other Pacific Islanders.

REU projects feature the high-quality interaction of students with faculty and/or other research mentors and access to appropriate facilities and professional development opportunities [2]. Active research experience is considered one of the most effective ways to attract talented undergraduates to, and retain them in, careers in science and engineering, including

careers in teaching and educational research. Faculty and graduate students act as active mentors for the participating undergraduates. Typically, research institutions are set to provide mentoring experiences for graduate students. Mentoring activities for graduate students are successful, as evidenced by the rise in the number of women pursuing graduate degrees over the years [3-4]. Recent statistics are shown in Figure 1.

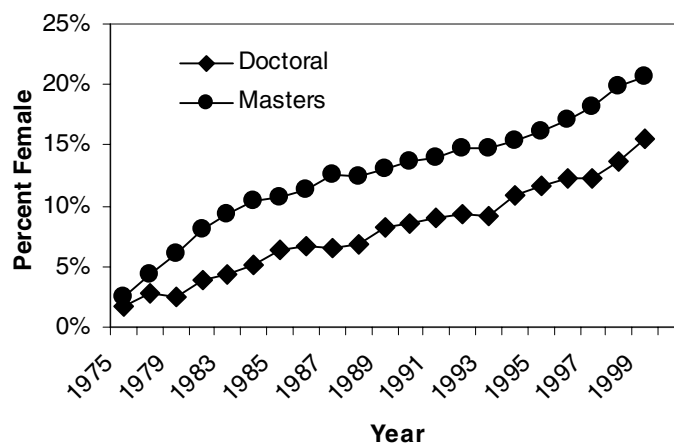


Figure 1: Earned Master's and doctoral degrees in engineering by women (NSF).

Research experiences can expose undergraduate students to the creativity of the research process and enable them to understand the value of graduate studies. Students can also see a direct application of their acquired knowledge from formal coursework. There are currently over a hundred engineering REU sites in the USA. These programmes are very successful in cultivating US student interest in, and aptitude for, research careers in science and engineering [5-6]. Similar sites are also offered by other NSF divisions such as the following:

- Astronomical sciences;
- Atmospheric sciences;
- Biological sciences;
- Chemistry;
- Computer and information science and engineering;
- Department of Defense (DoD);
- Earth sciences;
- Education and human resources;
- Engineering;
- Ethics and values studies;
- International science and engineering;
- Materials research;
- Mathematical sciences;
- Ocean sciences;
- Physics;
- Polar programmes;
- Social, behavioural and economic sciences.

An REU site that focuses on pollution prevention and sustainability was established at the College of Engineering at Rowan University, Glassboro, USA, starting the summer of 2001. Pollution prevention and global sustainability are essential in the development of a technology workforce that cares about the environment and the social impacts of the development of technology.

The REU Site at the College of Engineering was established with the following objectives:

- *Generating* excitement among the undergraduate students by providing them with the opportunity to work on engineering issues of national and international significance;
- *Providing* undergraduate students with the opportunity to work on fundamental research projects that have significant impacts on human health and the environment;
- *Increasing* the participation in research of women, underrepresented minorities and persons with disabilities;
- *Mentoring* undergraduate students by providing leadership roles by faculty and students;
- *Exposing* a broad and interdisciplinary group of undergraduate students to the scientific method used in the creation, investigation and documentation of a research project;
- *Encouraging* undergraduates (especially those from underrepresented groups) to pursue advanced degrees;
- *Sharing* research with communities outside the University (eg industry, pre-college groups, which include minorities) through presentations.

THE REU SITE

The College of Engineering at Rowan University was founded after a major donation in 1992 from the Rowan Foundation. The Rowan University College of Engineering has a brand new engineering building, including state-of-the-art equipment and computer resources, and a dedicated and extremely competent faculty. The College has four engineering disciplines: namely Chemical; Civil and Environmental; Electrical and Computer; and Mechanical. The engineering programme is famous for its non-traditional and innovative curricula. All four engineering disciplines involve students in research activities from the freshman through to the senior years. All students are required to take a two-credit engineering clinic class every semester.

This course allows students to participate in meaningful research experiences that allow them to develop problem-solving skills, understand the research process and also strengthen their technical writing and presentation skills. The freshman and sophomore clinics are more faculty-guided, while the junior/senior clinics are more open-ended and real world projects. The upper level clinics projects vary in content from basic to applied research, entrepreneurial ventures, community support activities, etc. Typically, these projects have funding from national, federal, state and local agencies and industries. In order to continue undergraduate research efforts during the summer, the REU programme was initiated in 2001.

Faculty who have backgrounds in engineering, physics, biology, chemistry and sociology are involved in the REU projects. A director and a co-director lead the entire project. The theme of *Pollution Prevention and Sustainability* is highly multidisciplinary and, as such, faculty from various engineering/physical and social science backgrounds can participate. Faculty are actively involved in mentoring activities for students during and after the duration of the REU project. Experienced Rowan undergraduate research assistants and Rowan graduate students work closely with REU participants. This three-tier structure (faculty, graduate student and undergraduate student) is very conducive to student learning, and also promotes an ideal mentoring environment.

The REU duration is for eight weeks, from early June to late July, every year. These funds allow support for 11 students. Each participant receives a stipend, room and boarding, meals and travel expenses. Campus housing is provided for participants.

The College of Engineering at Rowan University supports REU student recruitment activities. Recruitment activities include mailings (flyers, letters, e-mails to chairs, colleagues, etc) to all engineering universities, advertising in student newsletters, journals and magazines, selected phone contacts, visits and a Web site. Fliers are also sent to appropriate professional organisations and magazines, such as the ASCE, the Society of Women Engineers (SWE), the National Society of Black Engineers, the Society of Hispanic Professional Engineers, the American Indian Science and Engineering Society and the Women in Engineering Programmes Advocate Network (WEPAN). The Rowan University Educational Opportunity Fund/Minority Achievement Programme (EOF/MAP) also assists in recruitment activities. Participant selection is based on academic performance, recommendations and research interests and goals.

A Web site has been dedicated to Rowan University's REU. This site contains application information, as well as activities, important links and a list of publications. The Rowan University REU Web site for 2001-2003 was located at <http://sun00.rowan.edu/~everett/reu/reu.htm> and for 2004-2006 at <http://www.rowan.edu/colleges/engineering/clinics/reu0406/>.

NATURE OF STUDENT ACTIVITIES

As mentioned earlier, a common theme unifies the Rowan REU Site activities: pollution prevention and sustainability. Pollution Prevention (P2) equates to *source reduction* – preventing pollution before it is created, so there is less or no need to control, treat or dispose of it [7].

P2 is also a vehicle for *reinventing* traditional environmental programmes and devising innovative alternative strategies to protect public health and the environment. Sustainability is intimately related to pollution prevention and a responsible use of natural resources. Selected students work closely with faculty on current funded research projects in engineering that encourages pollution prevention and sustainable development. Faculty participating in the REU programme are actively involved in funded research and in mentoring graduate and undergraduate students. Project titles offered since 2001 are outlined below:

- Toxicity of Nonionic Surfactants and Alternatives for Industry;
- Innovative Uses of Coal Combustion Products;
- Membrane-based Peptide Delivery;
- Preventing Non-Point Source Pollution in Semi-Urban Watersheds;
- Identifying Performance Parameters for Solar Alternatives;
- Pollution Prevention in the Metals Recovery Industry;
- Design of Flexible Water/Wastewater Systems for Minimum Discharge;
- Development of Optimal Conditions for a Biofuel Cell;
- Modelling Biodegradation Kinetics of Nonylphenol;
- Arsenic Removal in Drinking Water;
- BugPower: Fueling our Future with Microorganisms;
- Metal Removal from Industrial Wastewater;
- Developing *Green* Controlled Release Systems for Drug Delivery;
- Use of Jute in Strengthening Asphalt Mixtures;
- Stormwater Management in Chestnut Branch Watershed;
- Environmentally Conscious Disassembly of End-of-Life Computers;
- Chemical Kinetic Model Development and Flow Reactor Studies of Biodiesel Fuel Blends;
- Long-Life Smart Structures for Laser Data Transmission;
- Invertebrates as Bio-indicators of the Water Quality of the Maurice River;
- Design of Detoxifying Systems for Organo-nitriles Mediated by Cyanogenic Enzymes [8].

The first week of the REU programme is spent on orientation activities to help participants settle in. Orientation includes a campus tour, a social picnic at the College of Engineering, as well as an all-day trip to the South Jersey shore. Special attention is given to train students with laboratory orientation and safety procedures. REU participants are also paired with Rowan undergraduate and graduate students as mentors [9].

For the remaining seven weeks, students work on their research, under the supervision of REU professors and graduate research assistants. Students also attend formal seminars once a week to broaden their knowledge of contemporary environmental research, issues in engineering education and professional engineering practice. Some seminars focus on issues facing minorities in science and engineering, pursuing graduate school, gender sensitivity, and ethics.

Speakers are representatives from local industries, regulatory agencies and other academic research institutions. Each meeting ends with lunch and informal discussions. Three formal workshops are also offered during the REU programme. These focus on environmental ethics, diversity in the workplace and environmental justice and community impacts. Faculty with

expertise in these topics offer a daylong or half-day workshops. Students are encouraged to participate actively in enriching discussions, research relevant case studies and watch documentary videos on the topics. A weekly movie night is also held on Thursday nights. Movies are selected such that they encompass issues on gender, diversity, pollution prevention, sustainability, ethics, etc. Movies that have been shown include *Osama*, *Mr and Mrs Iyyer*, *Whale Rider*, *Rabbit Proof Fence*, *Legally Blonde*, *The Bhopal Express*, *Erin Brokovich* and *Class Action*.

Educational and social field trips are used to broaden the knowledge of participants beyond the laboratory and academic experience. Field trips are made to local chemical and manufacturing industries (eg Sony, Dupont, Astro Solar, Zeneca Pharmaceuticals) and Wastewater Treatment Plants that have research relevant concerns. Other field trips focus on local tourist attractions, such as the beautiful South Jersey Shore, Cape May, New York City, the Philadelphia Historical District, the Rodin and the Philadelphia Museum.

Students are required to make presentations to REU faculty and participants on their research progress around the fourth week. A final presentation and a written report is required. This helps students strengthen their verbal and oral communication skills. On the final Friday, students meet individually with their research professor to discuss their experience and finalise plans for technical publications and presentations. During the first, fifth and last weeks, an outside evaluator (College of Education, Faculty) meets with REU participants to evaluate their experiences. The evaluator determines the impact of the REU experience on participants through written surveys and exit interviews. The evaluator also conducts surveys beyond the duration of the REU to track students' progress at their respective colleges. The surveys and exit interviews provide valuable information vital for the improvement of the REU programme in subsequent years.

RESULTS OF THE REU PROGRAMME

Nearly 80 applications, on average, are received, and almost 60% of the applicants are female. The participant information for 2001 to 2004 is listed in Table 1.

Table 1: Gender and ethnicity data for 2001-2004.

Year	% Male	% Female
2001	18	82
2002	36	45
2003	27	55
2004	36	64

The table indicates there to have been good representation in terms of gender. REU efforts at recruiting a diverse group of students were also very successful. This is indicated for the 2001-2004 period in Figure 2.

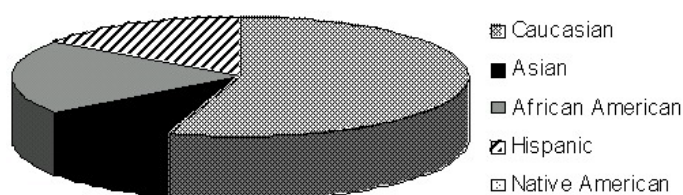


Figure 2: Participant ethnicity from 2001 to 2004.

The overall success of the REU programme is measured by the number of students who pursue graduate school. This is assessed by keeping track of the students via e-mails and surveys. Records indicate that, of the total 38 students who participated in the years 2001 to 2004, the proportion of students pursuing graduate school is 55% (ie 21). Out of these 21 students, 13 are female, while eight are male. The rest of the students who did not attend graduate school are either still in school or have a job.

REU evaluations for assessment are conducted at the start, at the middle and at the end of the programme. Students indicated that their Rowan University REU experience was extremely enriching, and professionally rewarding. Students were extremely impressed with the help and support of the College of Engineering faculty and students at Rowan University. They specifically mentioned that the ethics, diversity and community impact workshops were valuable experiences. Overall ratings by students were very strong. Table 2 lists the mean responses to certain questions defining success.

Table 2: Mean responses to certain questions defining success (6-point scale 6-strongly agree and 1-strongly disagree).

Statement	2001	2002	2003	2004
I learned a lot about research methodology	5.7	5.6	6.0	5.8
I will recommend this programme to other students	5.8	5.8	6.0	6.0
I am interested in attending graduate school to conduct research	5.5	5.2	5.8	5.8
My REU advisor did an excellent job of mentoring during the REU programme	5.8	5.7	5.8	5.7
I worked with a diverse group of people	5.5	5.8	6.0	6.0

CONCLUSIONS

The REU programme in pollution prevention and sustainability at Rowan University has been highly successful for the past couple of years. Student recruitment and selection, information dissemination, and assessment results from 2001 through to 2004 are very encouraging. A good percentage of students are attending graduate school. The results indicate that undergraduate mentoring programmes are

instrumental in preparing students for advanced degrees that are much needed in order to provide a specialised workforce nationally.

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REFERENCES

1. National Science Foundation (NSF), Research Experiences for Undergraduates (2004), <http://www.nsf.gov/home/crssprgm/reu/start.htm>
2. US Environmental Protection Agency, International Activities Home (2004), <http://www.epa.gov/oppt/international/index.htm>
3. Rowan, H.M. and Smith, J.C., *The Fire Within*. Cleveland: Penton Publishers (1995).
4. Jahan, K., Chin, S. and Basantis, M., Impact of research experiences on female engineering students. *Proc. Annual WEPAN Conf.*, San Juan, Puerto Rico (2002).
5. Marchese, A.J., Hesketh, R.P., Jahan, K., Chandrupatla, T.R., Dusseau, R.A., Slater, C.S. and Schmalzel, J.L., Design in the Rowan University Freshman Engineering Clinic. *Proc. ASEE Annual Conf. 3225*, Milwaukee, USA (1997).
6. Jahan, K., Marchese, A.J., Hesketh, R.P., Slater, C.S., Schmalzel, J.L., Chandrupatla, T.R. and Dusseau, R.A., The Rowan Engineering program: preparing students for the future job market. *Proc. 1997 Zone I Fall Meeting*, Wilmington, USA (1997).
7. Jahan, K., Tang, G., Gatling, S. and Freeman, K., Undergraduate research experiences in pollution prevention. *Proc. Mid-Atlantic ASEE Fall Conf.*, Baltimore, USA (2003).
8. Jahan, K., Everett, J.W., Orlins, J., Hesketh, R.P., Farrell, S., Mehta, Y., Hollar, K., Polikar R. and Savelski, M., Research experiences in pollution prevention. *Proc. ASEE Annual Conf.*, Nashville, USA (2003).
9. Jahan, K., Savelski, M., Orlins, J., Mehta, Y., Riddell, W., Farrell, S., Tang, G., Marchese, A., von Lockette, P., Richmond, C., Yang, C., Sukumaran, B., Mosto, P. and Miller, D., Undergraduate research in pollution prevention and sustainability. *Proc. Annual 2005 ASEE Conf.*, Portland, USA (2005).