120th ASEE Annual Conference & Exposition
FRANKLY, WE DO GIVE A D*MN
June 23-26, 2013

Paper ID #5920

# Undergraduate research and the smart grid: REU-Site: Engineering the Grid

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# "A report on the REU-site: Engineering the Grid"

*Abstract:* Undergraduate students participate in a ten-week long program engaged on research related to energy topics. The program includes coordinated professional development seminars on responsible professional conduct for engineers and research ethics, diversity awareness, as well as the graduate school application process. Along with their graduate mentors the participants also become role models in a system of "each one-mentor-one", interacting with high school teachers and students from a rural, underserved school district. Assessment results from program surveys indicate positive impact of mentorship, higher post-graduation career choices, and coordinated activities. Specifically by interacting with mentors female participants indicated that they gained more self-confidence as researchers than their male counterparts.

Index Terms: research experiences for undergraduates, beliefs, gender difference, mentors.

## INTRODUCTION

The Engineering the Grid research experience for undergraduates (REU) is a ten week program sponsored by the National Science Foundation (NSF) with an annual cohort of 10 students for 3 years. It was awarded to broaden the undergraduate multidisciplinary research teams at NC State beyond the NSF-sponsored Engineering Research Center (ERC) Future Renewable Electric Energy Delivery and Management (FREEDM) Systems where both investigators started both education programs: pre-college and college [1]. The goal of the FREEDM Systems is strongly centered on integrating scalable renewable generating energy sources into an efficient power electric grid. Today's grid, based on traditional electromechanical devices (i.e., circuit breakers and transformers), could not handle widespread use of renewable sources due to the lack of intelligent, coordinated controls and energy storage technologies.

The theme of energy and renewable resources is very attractive for students because it presents technical challenges to transform a green energy based society and weights the social responsibilities of reducing the impact of carbon emissions into the environment. In addition of the multidisciplinary nature, it is deemed to interest and engage while educating different concepts behind engineering and science research. Participants along with their faculty and graduate mentors become role models with their involvement in the "each-one-mentor-one" program with features of the engineer of 2020 [2, 3].

The participants also reinforce their learning in the research environment by sharing their experiences with high school students and assisting teachers to incorporate new concepts to be used in classroom curricula. By involving undergraduate students as mentors to high school students that may not have engineer role models they grow the potential to become leaders and advocates for energy literacy as became recommendation 4 from the National Science Board [4]. Some of the applicants themselves may not afford graduate education or have not even had research, yet they will be encouraged, informed to seek college careers in fields related to energy through mentored engagement in a real research setting.

## APPLICATION

### PARTICIPANTS

Students are recruited nationwide by postings on webpages of associations for undergraduate programs and emails to undergraduate outreach coordinator or undergraduate director of institutions that have limited research opportunities. One advantage is that the program is multidisciplinary and composed of faculty from different engineering departments, physical and mathematical sciences, targeting a large body of students.

The minimum overall GPA for application is 3.5. Applications were filled online through the program web site. The applicants provide personal information, gender, demographic, and upload official transcripts' files. One open window collects research interests in the program while another allows candidates to writes any prior experience or relevant information pertinent to their skills or interests. In addition to the submission of two names for recommendations that are requested and submitted electronically to be archived along with the application, the applicant ranks choices for research areas from a pull down menu.

The demographic profile of the participants indicated, as listed in Table I, as white (50%), with 30% African-American, 15% Hispanic, and 5% Asian. In the first two years the participants were distributed as more male (70%) than female (30%).

| Demographic Profile | |
|---|---|
| **RACE/ ETHNICITY** | Number (Percentage) |
| **White, non-Hispanic** | 10 (50%) |
| **Hispanic** | 3 (15%) |
| **Black, non-Hispanic** | 6 (30%) |
| **American-Indian or Native American** | 0 |
| **Asian or Pacific Islander** | 1 (5%) |
| **Gender** | 14 Males |
| | 6 Females |
| **Total** | **20** |

**Table I: Participants Gender and demographic profile**

Of the 20 undergraduate students who participated in the program in the first two years, 70% were rising juniors and 30% juniors/seniors in engineering and science: with majors in (35%) electrical and computer engineering, (15%) mechanical engineering, (15%) chemical engineering, (15%) materials science engineering, (15%) math and/or physics and (5%) computer sciences. A small fraction (10%) of the participants had double majors in both engineering and sciences (math/physics). There was a moderate balance between participants from universities with established graduate programs in STEM disciplines (55%) and small universities or colleges without those programs (45%).

A set of documents was developed on mentor and mentee guidelines [5]. All graduate students and faculty who signed up to mentor students were invited for an orientation and information session one month prior the program started. The mentoring package also includes material related to Young Scholars and Research Experience for Teachers. Activities are coordinated and focused for interaction among the different groups: for example, weekly sharing lunch meals and technical talks while off campus trips to visit utility plants or industries were scheduled later in the day to avoid interruption of the research activities.

### MENTORS, PROFILE AND PROJECTS

Faculty and their graduate students are solicited for their willingness to be REU mentors around the time the web page opens for applications [6]. Table II summarizes the profile and principal disciplines of the faculty mentors.

| **Faculty Mentors' Profile** | |
|---|---|
| Major Discipline | **Number** |
| Electrical and Computer Engineering | **7** |
| Mechanical Engineering | **5** |
| Materials Science Engineering | **2** |
| Textiles/Chemical Engineering | **2** |
| Nuclear Engineering | **1** |
| Industrial Engineering | **1** |
| Gender | **15 Males** |
| | **3 Females** |
| **Total** | **18** |

**Table II: Faculty Discipline and gender distribution**

The research projects revolve around the theme of energy and the electric grid, and are at developing a fundamental understanding of advanced materials used in making more efficient batteries, low cost photovoltaics, solar cells or light emitting diode, energy harvesting concepts and efficiency improvement, characterization of high power semiconductor diodes, issues

related to the next generation of semiconductor transformers, as well as solar arrays and the design of power converters, hybrid/electric cars .

Mentors submit a detailed description of the project along the background required for the undergraduate student such as major discipline (for example: EE, CS, CHEM) and specifically required courses (Organic chemistry, programming language or proficiency). This detailed information is essential in aiding the process of matching mentor to mentee, after the selection of top applicants for the program. Mentors and research areas are matched and assigned as the applicants accept. Table III contains some representative examples of research topics for undergraduate research that have been offered in the program. Some of the representative research topics offered are listed in Table III along the major discipline of the faculty mentor.

| Discipline | Project | **Research** area |
|---|---|---|
| **Textile Engineering** | Novel materials for Inexpensive Photovoltaics | Battery; Solar Cells |
| **Materials Science** | Nanoparticles/Metal Oxide coated Polymer Fibers for Solar Cells | Photovoltaic arrays, Plasma Processing |
| **Electrical Engineering** | Characterization of high voltage diodes | Power Semiconductor Devices |
| **Electrical Engineering** | Modeling Coils for Wireless Power Transfer | Electric vehicles, Power Electronics |
| **Industrial Engineering** | High-rate Nanomachining with Atomic Force Microscope | Nanomanufacturing; |
| **Mechanical Engineering** | Virtual Experiments with Lithium-ion Batteries | Batteries, thermal issues |
| **Electrical Engineering** | Transparent, Stretchable Electrodes | Nanoelectronics |
| **Computer Engineering** | Sensor Networks | Wireless Networking, Low Power |

**Table III: Sample of research projects in different disciplines**

## REU PARTICIPANT ACTIVITIES

During the ten week program the students are presented with a schedule of organized activities. Some are jointly co-sponsored by the NC Office of Undergraduate Research and other summer programs to create developing inter and multidisciplinary network. A typical schedule of activities includes:

- Campus, safety and laboratory training
- Professional development seminar on ethics and responsible conduct
- Workshop on public presentation skills and career planning
- Graduate school application and fellowship opportunities at agencies as well as graduate students panel
- Laboratory tours on campus, research buildings, power utilities sites (nuclear, coal, solar farm)
- Technical seminars from visiting scientists, engineers, government representative, and faculty
- Social events on campus: welcome reception, NC Natural Sciences Museum visit, picnics
- Meetings with research group led by faculty mentor
- Poster session jointly held with REU students from NC State undergraduate research program

## PROCEDURE

On the first day of the program, participants are invited for a welcome and orientation breakfast with the program directors and social interaction. Afterwards they are asked to answer a survey of attitudes, beliefs, and expectations related to their majors and experiences. An encrypted numeric ID (privy only of the program support assistant and destroyed at the end of the program) is created for each participant with the main purpose of analyzing the gender related questions.

### MATERIALS

**SURVEY CONTENT:** The survey instruments were chosen to collect program evaluation responses and to measure beliefs, expectation/perceptions of engineering and science careers, self-efficacy, and other constructs. From the surveys, specifically the NSF-funded Assessing Women and Men in Engineering (AWE) project at Penn State University provided several of the instruments used in this study [7]. After a review of the literature, an assessment plan was developed to focus on career, confidence, skills, attitudes, and behavior of participants. The survey with open-ended and Likert style questions was given to the participants on the first and at the last day of the program. The mean scores from the Likert-style questions (where: 1 = not at all, 2 = small extent, 3 = moderate extent, and 4 = great extent) were tabulated to determine

pre-post gains. Some items were answered using a 1 (strongly disagree) to 5 (strongly agree) scale. Open ended questions included free format text for collection and to provide feedback for ongoing program management and refinement. The survey data was also used to assess the overall success of the program according to the students.

## FINDINGS

The student surveys addressed the participants overall desire to continue and graduate on their current majors. Table IV below shows the rating average that over the duration of the program the number of students felt fairly confident or very confident in their enrollment in an engineering program.

To address more specifically the program influence, Table V displays the pre and post results were incorporated in the second year to addressed of the show very little shift over the pre and the end of the ten-week program survey period on their intentions.

| | Male (N=14) | Female (N=6) | Total (N=20) |
|---|---|---|---|
| You will be enrolled in any major in the college or school of engineering in the next year? | 3.50 | 3.67 | **3.55** |
| You will complete any engineering degree (or engineering major)? | 3.36 | 3.50 | **3.40** |
| You will complete any degree (any major)? | 3.79 | 4.00 | **3.85** |
| You will keep your chosen major through graduation? | 3.93 | 3.83 | **3.90** |

**Table IV: Career pursuit questions**

The female confidence levels in completing an engineering program dropped because the question referred specifically to engineering degree and not to math or physics disciplines as well as the small sample size.

The majority of participants stated that their main reason for choosing the REU program was that they want to learn more research in relation to engineering and science careers, gain valuable experience within the engineering field through research, and learn to do things that they did not think they could do. Other survey results reveal that participants have gained confidence in their interest in research, career choices and less in teaching.

In post survey responses 90% of the participants said that they had positive experiences with 90% approval and would definitely recommend the program to other students.

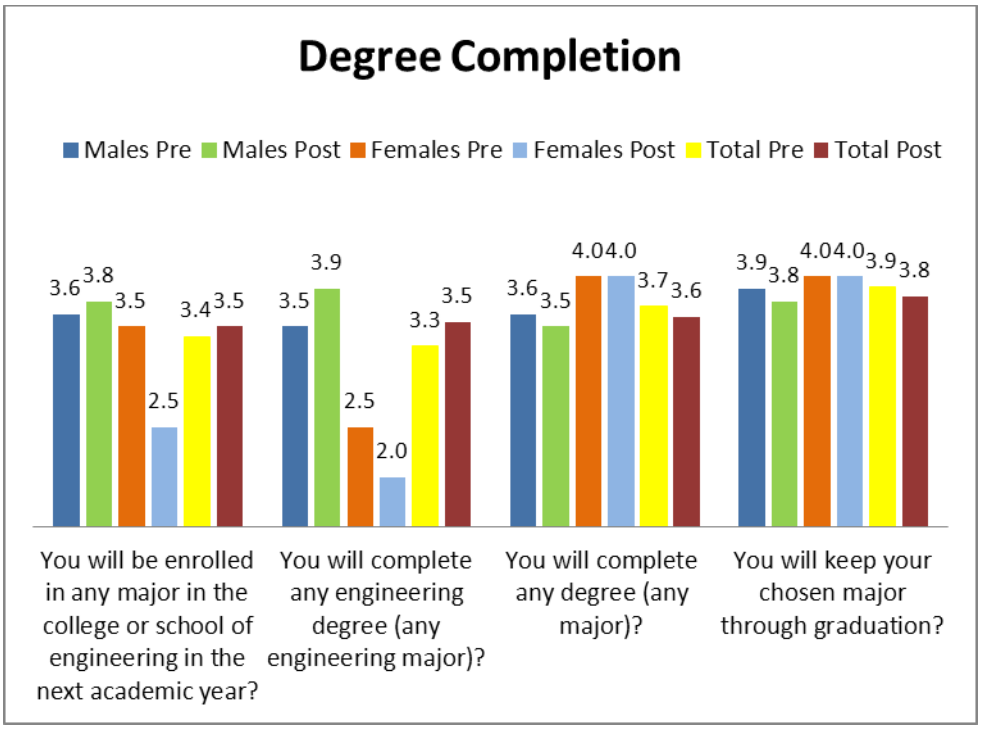


**Table V: Degree enrollment and completion**

**VALUE**

| Would you recommend that other students participate as an REU in this program? | Yes | No |
|---|---|---|
| | *90%* | *10%* |

The surveys (Table VI) also indicate that the REU program might have a positive impact on the participants' career even if they indicated that the research contents were not going to be immediately impact on their course work. However most of them showed a positive confidence that the REU program would increase their skills for a technical job.

An open comment window followed the yes/no question. The most commonly stated area for improvement in the overall program was often cited the project choices, preference for doing more experimental research, and/or personal growth related to mentor choices.

Males and females enjoyed their research projects as displayed in Table VII while females gained more self-confidence as researcher than their males counterparts. Notwithstanding females indicated that their mentors contributed more positively on the program's impact for them than their male colleagues On the other hand the female participants indicated a decreased confidence on their oral communication with their mentors in questioning technical work.

| | Males | Females | Total |
|---|---|---|---|
| The quality of the research met my expectations | 3.43 | 3.33 | **3.40** |
| The knowledge I gained is relevant to my current studies | 3.29 | 3.17 | **3.25** |
| You will be enrolled in any major in the college or school of engineering in the next year? | 3.50 | 3.67 | **3.55** |
| This program has encouraged me to further my studies and/or research in this field | 3.07 | 3.17 | **3.10** |
| This program will help me obtain a job in the future | 3.71 | 3.50 | **3.65** |
| My participation in this REU program was important to my career decisions | 3.71 | 3.50 | **3.65** |

**Table VI: Program skills and career decisions**

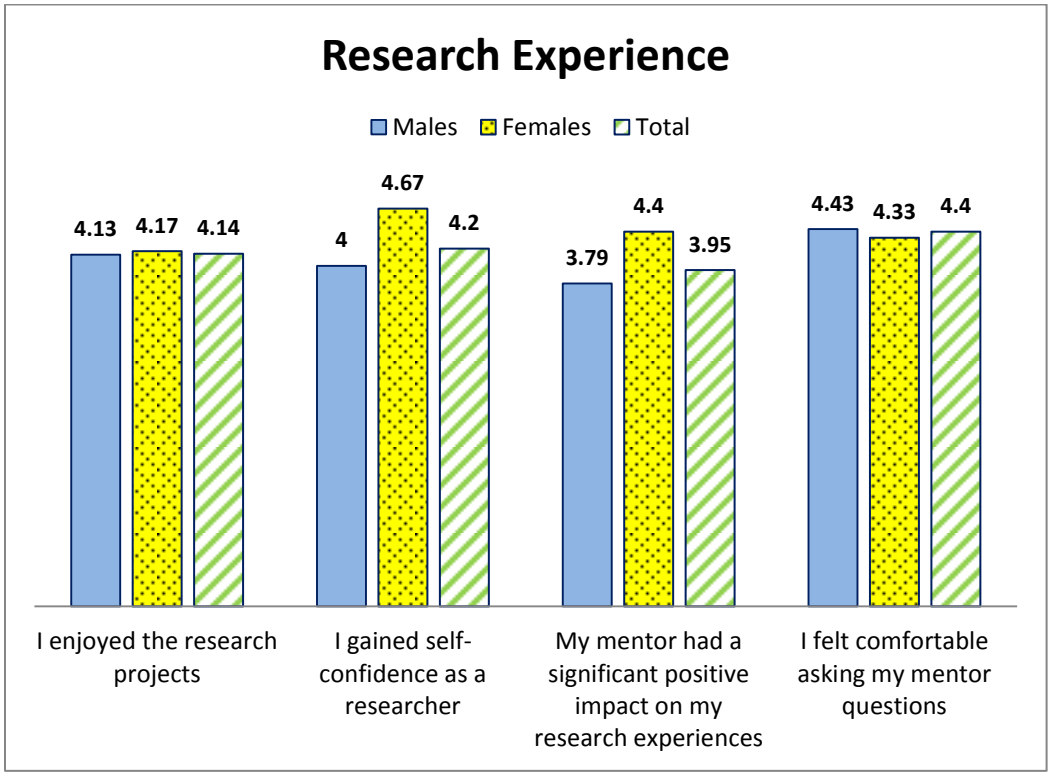


**Table VII: Program skills and career decisions**

Survey questions were collected on the participants about their perspectives on types of science, technology, engineering and math (STEM) careers are available after participating in this program. Table VIII show that the participants have a different perspective regarding those careers: all have a positive interest in connecting with a career working in STEM, overall more females than males indicated that. In research, more males than females indicated increased interest while in teaching males indicated a decreased interest relative to their female counterparts.

**Conclusions:**

This 3-year research program for undergraduate students described here involved 20 students and will be in his final year at the time of this report. The multidisciplinary topic of research is appealing with survey results indicating that most of the participants would recommend this kind of program to others.

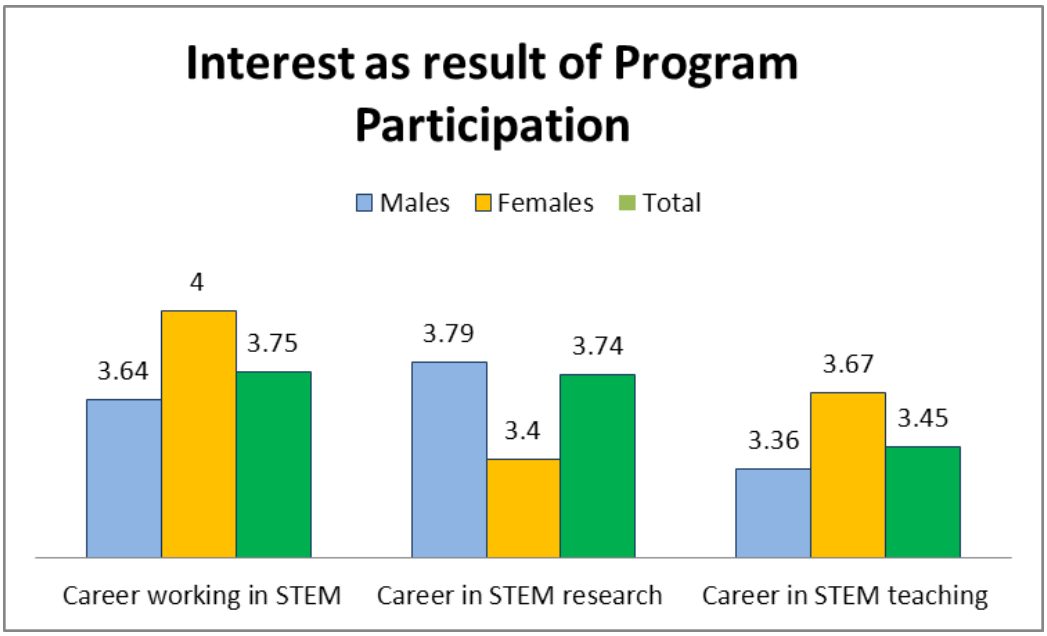


**Table VIII: STEM Career choices**

*Acknowledgements:* This program was supported by National Science Foundation under grant EEC# 1005838. The authors thank all the students and mentors that have participated in this project, the input from the program assistants: Marie Panepinto, Iris Wagstaff and Asia Battle-Gray, and in the early phase of the project, discussions with Kristen Molyneaux and Pat Dixon.

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