AC 2010-276: PRECOLLEGE OUTREACH WITHIN THE FREEDM SYSTEMS CENTER

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Precollege Outreach within the FREEDM Systems Center

Abstract

The precollege program in the FREEDM research center has completed its first year with 31 participants. The precollege outreach effort at the three ERC university partners is targeted at middle and high school teachers and students. The program consist of three major thrusts: (1) a research experience for teachers, (2) a Young Scholars program for high school students, and (3) summer camps for middle school girls and minorities. Along with faculty, graduate and undergraduate students act as mentors to both the teachers and precollege students. Assessment data are being collected to gauge the efficacy of the precollege program.

Introduction

The Future Renewable Electrical Energy Delivery and Management (FREEDM) Systems Center is an NSF-supported engineering research center (ERC). The vision of FREEDM is an efficient power grid integrating highly distributed and scalable alternative generating sources and storage with existing power systems to facilitate a green energy based society, mitigate the growing energy crisis, and reduce the impact of carbon emissions on the environment. An important component of this ERC is the precollege outreach activities at three university campuses in the southeast and southwest. The lead university is North Carolina State University (NCSU) and the two partner institutions are Arizona State University (ASU) and Florida State University (FSU).

The importance of enhancing science, technology, engineering and mathematics (STEM) education in middle and high schools continues to be noted. Key issues guiding the programming for the FREEDM Systems Center include:

- the aging of the power industry workforce (we need students to consider power engineering as a career since the need is increasing).[1]
- Our society is increasingly technological and a STEM-literate population is critical to handling the problems that we will be facing in the coming years. [2]
- Students make decisions about STEM courses in middle school that have lifelong ramifications – not taking algebra means that a huge number of career choices become out of reach; selecting a path in which students do not take enough math and/or science in high school leads to problems in college where students lack the background to enroll in courses required for various fields of study.[3]
- Students, especially students from underrepresented groups, are often unaware of STEM-related careers that are available to them; programs like this show students possibilities that they might not have known exist otherwise.[3]

Precollege Program

The goal of the precollege program is to develop and assess long-term partnerships with middle and high schools, teachers, and students to enhance teachers' engineering content knowledge and pedagogical methods, bring engineering concepts into the classroom, involve precollege students in research, and increase the diversity and enrollment of domestic students in university degree programs. Having completed its first year, the FREEDM Systems Center is engaging precollege teachers and students in middle and high schools in activities that include graduate student classroom visits, a Young Scholars program, teacher curriculum development workshops and research experiences, and summer camps in renewable energy for girls and underrepresented minorities. A strategy of these programs is to leverage the strong interest that middle and high school students have in environmental science to stimulate student interest in engineering careers focused on energy. The Center is attempting to impact over 13,000 middle and high school students and teachers in a set of 14 partner schools with great racial and economic diversity (see Table I).

Table I. ERC Precollege School Partners

School	Student Population	Minority Population	Eligible for Free or Reduced Cost Lunch
High Schools (5)			
Eastern Alamance High School, NC	1,150	29%	22%
Southern Alamance High School, NC	1,124	17%	19%
Carl Hayden High School, AZ	2,376	92%	93%
FSU Charter High School, FL	618	38%	24%
Godby High School, FL	1,298	65%	38%
Total High School Students	**6,566**		
Middle Schools (9)			
FSU Charter Middle School, FL	479	86%	78%
Broadview Middle School, NC	734	62%	70%
Fairview Middle School, FL	845	73%	52%
Graham Middle School, NC	640	30%	34%
Hawfields Middle School, NC	622	47%	43%
Raa Middle School, FL	800	46%	36%
Turrentine Middle School, NC	927	16%	21%
Western Middle School, NC	766	35%	33%
Woodlawn Middle School, NC	583	38%	24%
Total Middle School Students	**6,396**		

The ERC precollege education objectives are

- engage in sustained partnerships with students and teachers in select middle and high schools serving populations with maximum diversity;
- engage teachers in a supportive RET atmosphere, culminating in a combination of content knowledge and best teaching practices in high-quality, pre-engineering curriculum activities to be tested in classrooms and shared openly on the Internet;
- provide research experiences for high school students through a Young Scholars program pairing promising students with graduate student research mentors with the goal of entering projects into the Intel International Science and Engineering Fair;[4]

- engage middle school girls and minorities in summer science camps focused on renewable energy systems to encourage interest in future science careers and increase diversity in the field of power engineering;
- sponsor a Renewable Energy "event" at the NC Science Olympiad, awarding the winner a $1,000 scholarship to any partner university;
- engage ERC graduate students and REU students in all precollege outreach activities to improve communication skills about engineering and mentor younger students; and
- assess the impact of precollege outreach efforts on partner schools, teachers, and students.

The FREEDM precollege program is one component of the multifaceted educational initiatives of the Center. As illustrated in Figure 1, the university-level and precollege education programs consist of a graduate education component, a research experience for undergraduates (REUs) element, and the precollege effort. Interconnections exist between these constituents; for example, graduate students act as mentors to both the REUs and the precollege participants.

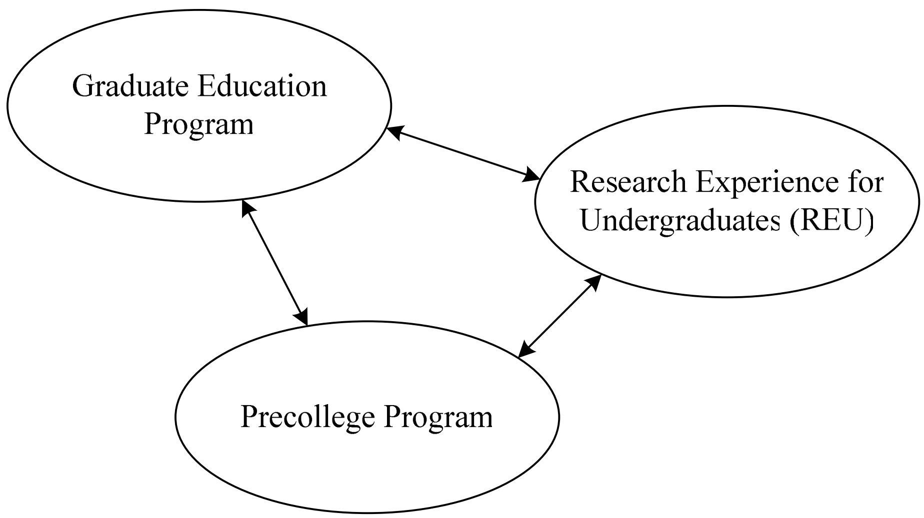

Figure 1. Overall FREEDM University and Precollege Education Programs.

Graduate Student Mentoring

Center graduate and undergraduate students are involved in all precollege education activities as mentors, workshop technical assistants, and visiting engineers in school classrooms. University students may provide content support to teachers and students or make presentations on aspects of their education, research, and hobbies of interest to younger students. Some are selected for "Meet An Engineer" materials and podcasts in which diverse students discuss their interests, academic paths, and motivations (see www.science-house.org/freedm/videos.html). An ERC graduate student is matched as a mentor for each Young Scholar and REU student. Both graduate and REU students have opportunities to serve as role models and science activity teaching assistants for science camps for middle school girls and minorities.

There is no doubt that mentors are useful to both male and female students; however, there is evidence that mentoring is a vital part of career development for women and minorities.[5]

Research shows that students feel most comfortable with mentors like themselves and vice versa, i.e., the same gender and ethnicity.[6] Good mentors are able to share life experiences and wisdom, as well as technical expertise. They are good listeners, good observers, and good problem-solvers. They make an effort to know, accept, and respect the goals and interests of a student, and they establish an environment in which the student's accomplishment is limited only by the extent of his or her talent. Mentors to successful women and minority students should understand—or at least appreciate—a female or minority student's perspective.[7] Therefore, graduate students are required to attend the "Mentoring for Diversity" seminar presented that is available as streaming video on the ERC website.

Graduate students are challenged to make the mentees a full participant in laboratory activities, help plan a research project that builds on mentees' individual interests, and teach mentees basic laboratory safety, research methods, and ethics. Graduate students are also responsible for maintaining contact with mentees through graduation from high school or college, continuing to encourage their scientific and engineering interests, and updating them on laboratory and Center activities. REU students assigned to the same laboratories as Young Scholars also take part in the Scholars' mentoring.

Research Experience for Teachers

Once facet of the FREEDM precollege program is the Research Experience for Teachers (RETs). Middle and high school science teachers are recruited from partner schools for four-week RETs at partner campuses each summer. Each RET experience consists of three weeks participating in ERC research followed by a one week hands-on curriculum development workshop. Participating teachers receive a stipend during their RETs as well as a kit of science activity materials that will allow them to conduct the science activity developed in the workshop in each of their classes. Teachers may repeat the experience for a second year. The ERC is to support approximately 50 RET slots over five years.

During the four-week summer research experience, the teachers are paired with faculty and graduate student research mentors in university laboratories, learning lab procedures, participating in research, and gaining insights into research on renewable electric energy and power systems. Teachers also participate in a hands-on curriculum development workshop, conducting inquiry-based activities related to electricity and renewable energy sources and working in teams to develop and adapt precollege engineering activities; this includes time set aside to identify key K-12 science curriculum objectives from each participating state, and to develop stimulating, age-appropriate curriculum materials related to renewable energy systems.

ERC precollege education directors and staff assist in identifying key K-12 science curriculum objectives within each participating state, recruit teachers from partner schools for RETs, and help them develop stimulating, age-appropriate curriculum materials related to renewable energy systems. ERC staff work with teachers as they use their RET-developed modules in the classroom and assess the results. Using this feedback, the ERC intends to develop the materials into a module format appropriate for sharing with other teachers.

Young Scholars

Talented rising high school juniors and seniors are recruited from partner schools as Young Scholars in ERC research laboratories. Announcements are distributed through partner high school science and mathematics teachers. Young Scholars are competitively selected based on a personal essay and teacher recommendation(s). The ERC plans to offer approximately 100 Young Scholars positions over the five years. Based on the high populations of minorities in the ERC partner schools, it is expected that a diverse group of Young Scholars will be attracted to the program.

Mentored by graduate and REU researchers, each Young Scholar completes a research project and is encouraged to submit the project to the Intel International Science and Engineering Fair via local and state competitions. This program is intended to help capable young people develop an interest and seek college careers in fields related to renewable energy systems through mentored immersion in a laboratory setting. The Young Scholars may participate in up to two paid, five-week summer research experiences. In the second summer, they will continue research, preparing papers to be submitted to the Intel Science Talent Search. Later, Young Scholars will be given priority for the ERC's REU opportunities, and eventually for graduate fellowships.

Summer Science Camps for Middle School Girls and Minorities

In addition to the Young Scholars program, separate science camps are conducted for middle school students. The ERC sponsors a one-week summer science camp for middle school girls each year at NCSU, and a camp for middle school underrepresented minorities at ASU. A total of 150 campers are expected to participate over the course of five years. Graduate and undergraduate students affiliated with the ERC serve as teaching assistants and role models.

Middle school students visit university and industry facilities, interact with engineering faculty and students, engage in hands-on, inquiry-based activities, and develop projects that are presented to family and friends at the end of the camp. Science activities (developed by the RETs and graduate students) are related to electricity and alternative energy sources, thereby leveraging the current heightened interest in energy and environmental issues to help students begin to see themselves as scientists in these fields.

Assessment

Summative and formative assessment that permits longitudinal follow-up with all precollege participants in the ERC is being conducted. To prepare for this human subjects data collection, precollege directors applied to the Institutional Review Board at each university, with an application package including the survey instruments and informed consent letters for teachers and students. In addition to quantitative measures of participation and diversity, the assessment includes attitudinal measures of problem-solving and self-efficacy.[8,9,10] Also, qualitative reflections completed by teachers, Young Scholars, and middle school students are collected online at the completion of each activity. Mentors and ERC precollege staff perform longitudinal follow-up electronically. This follow-up itself may have a positive effect on precollege participants, helping them see themselves as part of the ERC and stimulating further interest in engineering degrees.

Program Highlights and Lessons Learned

Some of the details from the various facets of the precollege program are presented in this section, along with lessons learned.

Partner Schools

The partner schools were initially selected because of existing relationships with partner universities and a strong interest in participating. However, public schools and their administrators sometimes change quickly. Although we were originally certain of partnerships with the identified school systems, a few schools chose to withdraw from participation. By the same token, other schools in the school systems became interested and were willing to go through the steps to become a Center partner. In the case of one school, the minority population was found to contain a significant number of undocumented individuals, making them ineligible for the precollege program due to restrictions on the distribution of stipends. These challenges are encouraging the expansion of the list of partner schools.

Participants in 2009

The first summer programs of the FREEDM precollege outreach effort were conducted in 2009. The total number of participants was 5 public school teachers, 12 Young Scholars (high school students), and 14 middle school campers. Overall, the participants were about evenly divided between male and female. Whereas all of the teachers were white (non-Hispanic), the students were evenly divided between white and underrepresented (with 31% of the total being African American). A surprising issue was the few number of applicants, especially teachers, given the present recessionary times and lack of jobs (e.g., student summer employment).

Young Scholar Program Activities

Activities for the Young Scholars were planned to cover an 8-hr day. Table II shows representative activities scheduled for the first week of the program. Daily program activities included:

- Introduction, laboratory safety, research topics assignments,
- Lectures by faculty and research associates,
- Actual hands-on laboratory and research work,
- Formal meetings with the research project team,
- Seminars and webpage demonstrations (e.g., see the electric power applets[11]), and
- Young Scholar presentations.

Basic information regarding electricity generation, including renewables, was also presented to the students and teachers in order to provide them with an overall understanding of the issues surrounding green energy utilization. Topics presented include history and pioneers of electricity transmission and distribution, energy resources, electric generation methods, and dc/ac conversion (since renewables such as photovoltaics and even wind may make use of such technology).

Table II. Daily Schedule for Young Scholars

First week: June 1–5, 2009					
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
08:00	Orientation & Paperwork & Lab Safety	**Campus Tour**	**Power Systems Overview 2**	**Power Systems Overview 3**	**Online surveys**
09:00	Overview & EXPECTATIONS			Practice using DOE website – **gen pie chart**	
10:00	Q&A about power in USA		Web – TCIP Java applet 1 (+ pdf)		Finish PowerPoint presentation
11:00				GRA presenter	
12:00	***LUNCH***				
01:00	Research lab tours *meet prof, gra*	Where do I find good research material?	Research the term 'load profile'	Select-a-project	**Research**
02:00	**PwrSysOvr 1.1 + Q&A**			**Research**	
03:00		Review projects	**Discuss results of web searches (Edison … etc.)**	Start PowerPoint presentation	1pg week summary
04:00	INTRODUCE PROJECT OPTIONS	**Power Systems Overview 1.1 (continued)**			10 min presentation What I've Learned - My Research

During the first week, lectures by faculty members and graduate students were intended to introduce and explain the various research fields as well as motivate student interest in technical fields of study. The speakers tried to recruit participants (both students and teachers) into their specific ERC research projects. From the participants' points of view, those lectures promoted understanding and cleared any confusion about the list of available research topics.

The participants had access to one laboratory as their working office and another laboratory where the experimental research was conducted as well as access to a computational laboratory to facilitate Internet research, calculations, report writing and preparation of PowerPoint presentations. In addition, both on- and off-campus field trips were carried out in the summer program. As examples, an on-campus tour of the science and engineering library was arranged; and an off-campus trip was taken to a solar test and research facility.

Young Scholars were asked to submit a short weekly report to show their progress and make a progress presentation every week. This reporting was of a great help in developing and improving the program each week. The increased maturity of the oral presentations over the course of the summer program was remarkable.

As of the writing of this paper, the application process for the second year summer program has just begun, and the five 2009 Young Scholars have already applied for summer 2010.

Research Experience for Teachers

Several well-prepared experiments were provided to the teachers including

- Solar Energy Science Projects from the National Renewable Energy Laboratory (NREL),[12]
- Science of Energy and Learning and Conserving kits from the National Energy Education and Development (NEED) Project,[13]
- Capacitor-Aided System for Teaching and Learning Electricity (CASTLE) from PASCO,[14]
- Renewable Energy Activities – Choices for Tomorrow from NREL,[15] and
- Various (71) lesson plans from the IEEE at www.tryengineering.org.

The best materials connect the activities to science standards thereby reducing the effort required for teachers to adapt the materials to particular requirements in their home state. In one instance, a teacher adapted the materials to create a high-school level laboratory experiment on a solar hot water heater (in keeping with the renewable energy theme of the ERC). For additional resources, please see www.science-house.org/freedm/pcresources.html.

To allow the teachers are various sites to collaborate during the summer, an advanced Internet conferencing system was employed. The RETs at all three sites had virtual meetings to discuss lesson planning. The videoconferencing capability allowed them to see each other along with audio discussion and real-time document sharing.

Assessment Instruments

The teachers and Young Scholars completed various survey instruments as well as online journals. The two surveys provided to the teachers were the RET Network Survey[16] and the Science Teaching Efficacy Belief Instrument (STEBI)[10] that assesses teachers' teaching self-efficacy. Both these surveys were administered prior to the program, and the RET and STEBI were re-administered on the last day and 3-6 months after the summer, respectively. The high school students completed the following instruments:

- TPS: Technology Problem Solving Survey – assesses ability to solve technology related problems;[9]
- LAESE: Longitudinal Assessment of Engineering Self-Efficacy (High School version) – measures high school students' levels of self-efficacy in engineering related issues, questions, problems, or activities;[8]
- PDQ Participant Survey – post participation program survey;[8] and
- PAS: Pre-Activity Survey for High School-Aged Participants, Science – examines results of items that address participant satisfaction and suggestions to help redesign the activity for maximum impact.[8]

The schedule for deploying these surveys is given in Table III. Middle school students completed only the PAS for Middle School-Aged Participants, Science, but using the same schedule as that of the high school students.

These instruments were administered during summer 2009. Preliminary results show that student perspectives have been broadened regarding the types of jobs available to scientists. Furthermore, the students have exhibited an increase in connecting science with their daily lives. Other survey results reveal that teachers have gained confidence in their teaching ability and an increase in their interest in applications of mathematics and science. The research team still has questions about the results and plans to add additional prompts in the qualitative measures to uncover more of the students' responses about science and science careers. The small sample size does not permit forming any general conclusions, but as more participants are added over the next four years, a more rigorous analysis of the data should be possible.

Table III. Deployment Schedule for Surveys of Young Scholars

Instrument	Pre Program	First Day	Last Day	Post (3-6 months)
TPS	X		X	
LAESE	X			X
PDQ Participant			X	
PAS		X	X	X

Summary

The FREEDM precollege program has finished its first year with 31 participants. The precollege outreach effort targets middle and high school teachers and students. The program consist of three major thrusts: (1) a research experience for teachers, (2) a Young Scholars program for high school students, and (3) summer camps for middle school girls and minorities. Although faculty provide mentoring for the Young Scholars, the Center graduate students and REU students also provided highly valued mentoring. Longitudinal assessment data are being collected and will be analyzed as part of the Year 2 and future work of this project.

Acknowledgment

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