Integrating Research in Sustainable Energy and the Environment across Disciplines through a NSF funded REU Site

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Abstract:

This REU Site supported by the National Science Foundation's Division of Engineering Education and Centers is designed to develop and implement a model environment for multidisciplinary collaborative efforts where research and education are tightly integrated around the different facets of energy research. It seeks to provide an impactful summer research experience in the emerging field of sustainable energy and expand research opportunities for underrepresented students. The program is structured to teach students how to formulate research questions as well as how to develop and modify research plans with the guidance of their research mentors. Students will learn to work independently and to collaborate with other group members as they conduct research in specific topics in energy research. This will enable them to understand their own levels of aptitude and interest in a career in science, technology, engineering, and mathematics (STEM) and give them the tools to prepare for the next stage in their education and career development. Students will report and present their research results in multiple settings. In addition to the hands-on collaborative research experience, technical and social activities will be incorporated into the program to provide students with a solid foundation in analytical, writing, and presentation skills and to enhance interactions between REU students and faculty mentors. The research, educational, and career mentorship provided by the program is envisioned to stimulate the students to look at their academic work in a new light and to provide a spark for possible careers in academic research or industrial innovation. Participating students will tackle various topics of energy research, interact with faculty mentors and students from different engineering departments, and develop a holistic perspective of energy research.

1. Introduction

The importance of sustainable energy research, and the impact of the current continuing path of utilizing fossil fuel on the environment, dominate a large segment of the scientific and political discussions in the US and world-wide [1-3]. Solutions to the energy challenges require a multi-pronged, balanced approach, addressing all possible alternatives. Energy research is a complex, multi-faceted theme where many disciplines interact to address different and sometimes contradictory components of the problem. Issues related to distributed energy generation from renewable sources cannot be detached from those associated with clean conventional energy and reducing energy consumption through new design processes. The environmental impacts of these sources as well as other methods of traditional energy generation cannot be ignored as we seek a sustainable energy future. Meanwhile, the social impact of energy sources and systems has drawn more and more attention in energy research theme.

Undergraduate research is an empowering experience for students and provides a multitude of benefits [4] and an opportunity to delve deeper into any subject. These students show an increased interest in a research career enabling them to become more productive researchers. Undergraduate research has also been linked to increased student retention [4]. An NSF sponsored study by SRI International has found that undergraduate research allows students to grow in a variety of ways,
including awareness, confidence and understanding. The effects were strongest among Hispanics/Latinos [5].

2. Program Background and Schedule

The REU site, starting in Summer 2015, is led by Texas A&M University-Kingsville (TAMU-K), located in a region blessed with various abundant natural resources that range from fossil fuel to wind and solar energy. In this region, most residents are Hispanic and poor, the issues on how the energy resources development affects the local communities’ social life in general and the value system of the local residents in particular, has not received any attention from either research organizations or local stakeholders. The REU site is aimed at increasing the energy research and technology in the region with specific emphasis on social as well as economic impacts of various energy sources and systems. The REU site is not only for introducing undergraduates (especially underrepresented students) to leading energy research, but also to strengthen collaborative links among the interdisciplinary group of faculty members at TAMU-K and build bridges to other institutions in this region and the US. TAMU-K has Hispanic population of nearly 70%. One of the key objectives of this REU site is increasing the number of US and underrepresented (Hispanic, African-American, and women) students in graduate education through early involvement of these students in research activities prior to graduation [6].

In order to attract high quality junior and senior students nationwide, the recruitment process started in November 2014 with the application deadline of March 2, 2015. The final selection is expected to be completed by the middle of April. The Summer 2015 program is scheduled from June 1, 2015 to August 7, 2015. The 10-week plan is detailed below:

- **Week 1 - Training:** The first week on TAMU-K campus will consist of full day interactive workshops to complete the following objectives:
  - Day 1 – Orientation and training regarding lab safety, campus resources. Basic introduction to research methodology using active learning techniques. Faculty mentors will give brief introduction to current active research in their group.
  - Days 2-5 - Training in the research methodology for independent investigation:
    - Each student will work with the faculty mentor and graduate student to formulate their own research question(s).
    - Develop a computer study and/or experimental measurement plan.

- **Weeks 2-9 - Research:** Students actively participate in research projects. Here, the students will:
  - Conduct the research according to plans developed in week 1.
  - Meet once a week with the full group to review progress with peers and meet twice per week within subgroups to provide peer critique at subgroup and full group meetings and respond to feedback from full group during the following week.
  - Document changes in research plans as needed.
  - Attend seminars given by faculty mentors, industrial speakers, stakeholders about various topics related to sustainable energy and the environment with emphasis on social impacts of energy sources and systems.
  - On the Friday of Week 5, each REU student will give a mid-term presentation on the progress of their research to all REU students and mentors.
•  **Week 10 - Reporting, Assessment, and Response:** During the final phase, the students will report on their individual research activities. In addition to their individual research reports, students will also collectively work, in consultation with the faculty mentors on a single “collaboration group report” summarizing their view of possibilities for future collaborative research projects. An oral presentation competition will be organized for the best poster award and will provide an opportunity for winner to present his/her work at a national conference. The presentation session will be open to all students, faculty, mentors, with two judge panels-faculty panel and stakeholder panel. This is part of the dissemination plan and aims to publicize the event and increase the confidence of the students.

3. **Program Design with Multidisciplinary Settings**

3.1 **Research project design**

The REU site is multidisciplinary in nature and focuses on different aspects of sustainable energy research. It offers undergraduate students an opportunity to gain new insights and knowledge in the broad spectrum of energy challenges including: 1) renewable energy; 2) clean conventional energy; 3) energy policy, environmental and social impacts. The REU site provides undergraduate students with an in-depth experience in one of the areas related to sustainable energy research with a focus on experimentation, simulation, and numerical modeling while helping them build a broader perspective through the interaction with students and faculty involved with the project.

In Summer 2015, a total of 13 research projects (as listed in Table 1) are available for students to choose. Eight faculty members from five different departments in TAMU-K college of engineering participate in the REU site. Each project is designed to provide an in-depth research experience in its own area with hands-on, multidisciplinary, and collaborative settings [7]. Students are advised and mentored by one faculty member and one graduate student. The role of the faculty mentors and graduate students throughout the 10-week program includes exposing them to energy research, and more importantly, to provide training on how to create and arrive at independent research decisions [4, 8-9]. Meanwhile, students are given ample opportunities to share their research progress with the entire group through formal and informal presentations, which enhance students’ understanding and to broaden their perspective of the bigger scope of energy systems challenges. To enhance the student learning experience in program, discovery/inquiry-based learning principles [10-11] become integral features in the program. The participating students are divided into interdisciplinary teams of two to four members to discuss their own projects and share their ideas. Students are also required to submit a final report and to highlight their findings through an oral presentation. With those multidisciplinary research projects, the REU site has attract 54 applications for Summer 2015 from TAMU-K, universities in the region and over the entire nation, such as Georgia Institute of Technology, UCLA, Arizona State, etc. Ten students will be selected to participate the Summer 2015 REU program. Students’ activities in this REU site are comprised of research training, integrating research and education, and reporting, dissemination and continue mentoring.
Table 1: Available REU Projects in Summer 2015

<table>
<thead>
<tr>
<th>Project Title</th>
<th>Department of Faculty Advisor</th>
</tr>
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<tbody>
<tr>
<td>Impact of membrane material in the electrodialysis metathesis process for desalination of salty water</td>
<td>Environmental Eng.</td>
</tr>
<tr>
<td>Feasibility of using desalination concentrate for hydraulic fracturing fluid</td>
<td></td>
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<tr>
<td>Regeneration of Toxic Vapor-Saturated Activated Carbon via Microwave Energy</td>
<td></td>
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<tr>
<td>Distributed generation impact on congestion relief in electric power grid</td>
<td>Electrical Eng.</td>
</tr>
<tr>
<td>Influence of SCIG &amp; DFIG based wind turbine on the voltage stability of a weak distribution power grid</td>
<td>Mechanical Eng.</td>
</tr>
<tr>
<td>Two-axis position control of solar panels for maximum efficiency</td>
<td></td>
</tr>
<tr>
<td>Dynamics and control of wind turbines</td>
<td></td>
</tr>
<tr>
<td>Bridging FEA Software in Mechanical Engineering to Nuclear Reactor Neutronics Simulations</td>
<td>Chemical Eng.</td>
</tr>
<tr>
<td>Kinetic Monte Carlo Simulation of Hydrogen Diffusion in Tungsten Bulk</td>
<td></td>
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<tr>
<td>Catalysis &amp; catalytic reaction engineering for biomass conversion</td>
<td></td>
</tr>
<tr>
<td>Catalysis &amp; catalytic reaction engineering for reducing SO2 emissions</td>
<td></td>
</tr>
<tr>
<td>Integration of photovoltaic thermal systems in residential buildings for energy saving</td>
<td>Civil Eng.</td>
</tr>
<tr>
<td>Application of seawater-source heat pump in hot climate</td>
<td></td>
</tr>
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3.2 Research training

It includes a formal training on the scientific method, the development of the research question and research plan, the research methodology, the importance of social and economic aspects of the research, and the professional ethics in research. The training is scheduled to be conducted in the first week of the program. The students are guided to formulate the research questions and create a task list for the summer project along with the project goals and objectives. To further enhance student understating on the importance of the social-economic aspects of the energy production, students are taken on field trips one day per week each summer to observe and study various energy-related engineering activities and its associated social and economic impacts. In addition, guest speakers from industry and stakeholders are invited to present seminars on topics related to sustainable energy and its social and economic impacts throughout the program. It is expected that these training activities will enhance the overall REU’ experience and develop the appreciation of technology and its associated social-economic values in modern society development.

3.3 Integrating research and education

One of this REU site’s objectives is to train the students’ research skills and prepare them for graduate studies. Weekly seminars are provided on the following topics: research methodologies, library research tools, technical writing, effective presentation skills, professional ethics, graduate school application and GRE preparation. The seminars are given by faculty mentors or guest speakers from the library and the English department.
3.4 Reporting, dissemination and continue mentoring

In the end of the first week, each student presents their assigned research topic as well as discussion of their project plans. The final week of the program is mostly dedicated to the reflection of the research experience in a collaborative manner with students from different groups reporting their findings. Reporting is required to be presented in a conference paper and an oral presentation format. The final activity of the project is a competition with both faculty judge panel and stakeholder judge panel. After 10 weeks of REU program, faculty mentors will continue mentoring students during the following academic year. In some cases, the REU project can be extended to the senior design milestone project. Students are encouraged to submit their research paper to conferences and journals.

4. Evaluation and Dissemination

Evaluation for this project will involve both internal and external evaluation tasks focused on collection of quantitative and qualitative data to address the following questions: (1) How has participation in this REU impacted students’ understanding of the research process, their skills in conducting research and presenting research findings, and their educational and career plans? And (2) How can this REU be improved for future student participants?

In order to answer the above two questions, several surveys have been designed, including pre and post surveys for the REU students, a post survey for faculty mentor, a post survey for graduate students, and a post survey for judges. A follow-up phone interview will also be conducted around October of each year to get additional information from those REU students. The results of the REU student pre-survey will be used to make early adjustments to meet the needs of the current cohort. Regular meetings with students and mentors will be scheduled to monitor students’ progress and identify concerns which can be addressed during the REU. These ongoing formative assessments using pre-survey data and input from student and mentor meetings will result in increased student learning and enhanced impact of REU participation.

The dissemination plan consists of several aspects: 1) REU students will develop a poster during the period of the program making it easier to subsequently make presentations on their research at their home institutions and other venues; 2) REU students will be encouraged to submit their research results to student conferences, regional and national conferences, and journals with focus on energy research. To encourage participation, travel stipends will be provided as award to selected REU students who present their work at conferences; 4) The project management team will present methodology and lessons learned from the program at the national conferences; 5) Faculty mentors will be encouraged to organize technical sessions and give presentations at society wide conferences; and 6) Website/Facebook/LinkedIn for the REU site publicizing objectives and research achievements will be developed.

5. Summary

The REU site adopts an interdisciplinary and balanced approach as a guiding principle and will provide fundamental research training in emerging energy technologies. It features a 10-week interdisciplinary team approach to mentor students on energy research projects. The program aims
to create a dynamic multidisciplinary environment where research, education and outreach are combined to provide undergraduate students with an opportunity to conduct cutting-edge research in a timely research topic \cite{7,12}. Since undergraduate research sparks critical thinking and creativity among them, the objectives of this REU site are: 1) providing quality research opportunities to undergraduate students from all over the US in the different facets of sustainable energy research; 2) increasing the number of US citizens and especially underrepresented students (Hispanics, African-American, and women) who participate in graduate studies at TAMU-K and other institutions; and 3) using the REU site for building collaborative links among faculty and students from multiple disciplines from within the college of engineering at TAMU-K through energy related, interdisciplinary projects. As a result of the summer program, students are expected to be able to: 1) master the process of formulating a research question; 2) design, carry out and modify a research plan; 3) disseminate research results in oral and written formats; 4) work independently and collaboratively within a team; 5) recognize the different and sometimes contradictory issues related to a research question. Through participation in cutting-edge research with faculty mentors working at the forefront of their respective disciplines, students will engage in complex scientific studies on sustainable energy research topics.

Reference:


