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# **AC 2011-1039: AN ASSESSMENT PLAN FOR EVALUATING A FOUR SITE UNDERGRADUATE RESEARCH PROGRAM IN BIOFUELS AND BIOREFINING ENGINEERING**

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# **An Assessment Plan for Evaluating a Four Site Undergraduate Research Program in Biofuels and Biorefining Engineering**

## **Background**

The retention rates of students in engineering are very low and this is a concerning problem. Engineering requirements for admission are often higher, so more students should be succeeding, but this is not the case.<sup>i</sup> Of particular concern is the fact that women and minority students also have low retention rates. This is very troubling for American industry because a 10-30% rise in engineering jobs over the next few years has been predicted but graduation rates have decreased by about 20% over the last 20 years.<sup>ii</sup>

Much research has been done with regards to coming up with solutions to the problem of attrition. One proposed solution is an emphasis on undergraduate research. Nagda et al studied the impact of one undergraduate research program, UROP, on student retention at the University of Michigan.<sup>iii</sup> They found that, for White, Hispanic and African American students, participation in UROP positively affected retention for sophomores in the University. In another study, David Lopatto at Grinnell College in Iowa looked at the effects of participating in undergraduate research on decisions to go to graduate school.<sup>iv</sup> The results he got were very encouraging. About 91% of respondents indicated that their research experience sustained or increased their decision to go to graduate school with only about 4.7% indicating that their URE changed their plans away from post graduate education. One of his conclusions was that, generally, undergraduate students involved in research showed positive interests in continuing in science careers and postgraduate education.

The National Science Foundation has provided support for undergraduate research through The Research Experiences for Undergraduates (REU) program which provides funding for involving undergrads in on-going research programs.<sup>v</sup> The present study investigates one such REU program via the development of an assessment plan and an evaluation of assessment results.

## **REU Program Overview**

The Colorado Center for Biorefining and Biofuel (C2B2)/National Science Foundation REU Site Program is a 10-week summer program that involves participation from active researchers in a center specifically set up to facilitate collaborative research in biofuels and biorefining engineering including feedstock engineering, biological and thermochemical conversions, and process and product engineering. The center is a collaboration of the University of Colorado at Boulder, Colorado State University, Colorado School of Mines and the U.S. Department of Energy's National Renewable Energy Laboratory in the Denver, Colorado metropolitan area. In addition to an independent research project, written report, peer presentation and final poster presentation, undergraduate program participants engage in weekly group seminars, unique site visits to each of the four partner institutions and social activities targeted to unite program

participants in a cohesive cross-disciplinary research team. The goals of the undergraduate research program are as follows:

- Engage student participants in the pursuit of fundamental investigations of issues related to conversion of biomass to fuels and chemicals,
- Integrate the REU site to allow students to experience a collaborative, cross-disciplinary environment to investigate problems that require such collaboration to make meaningful progress,
- Train students in the skills and knowledge to conduct research,
- Recruit a competitive and diverse group of undergraduate students annually from across the country.

Each goal will be briefly described below:

*Goal 1: Engage students in fundamental investigations of converting biomass to fuels and chemicals* – Upon admission to the REU program, students are matched based on research interest to a research project and team at one of the participating institutions. Participants engage in weekly meetings with their respective principal investigator (PI) and research teams. In addition to working with a principal investigator, students are matched with a mentor graduate student or postdoctoral researcher that can provide guidance on everything from the research project execution and equipment maintenance to career experience and getting settled into living arrangements at their summer site. PIs and mentors define the project scope prior to students arriving in the laboratory, but should be willing to adjust the project objectives according to student experience levels and laboratory progress. While the REU program is intended to help undergraduate students become confident independent researchers, PIs and mentors provide an essential support system for students and have a large impact on participants' conceptions of research project success and progress.

*Goal 2: Integrate the REU site to provide students with a collaborative, cross-disciplinary research environment* – Group social and team building activities are organized throughout the program. Special emphasis is given to group social interaction during the first month of the program in order to ensure students become well acquainted with all other participants. Despite the multi-institution structure of program participants, students typically form friendships irrespective of research site placement and quickly plan their own group activities on weekends and holidays.

Group site visits to each of the four institutions enable students to meet faculty and researchers involved in all aspects of biofuels and biorefining technology development and investigation. Since different research expertise is distributed across the participating institutions, visits to each university and national laboratory help to acquaint students with scientific research and

laboratory equipment at each institution, thus expanding student exposure to different fields which play an integral role in the resolution of renewable fuel and chemical challenges. Students play an integral role in site visits; by sharing their research work with peers during group visits and acting as assistant tour guides, participants learn about intersections of their individual research with that of their peers. Such complimentary research connections are important to building participant understanding of cross-disciplinary scientific challenges involved in biofuels and biorefining. A commercial site visit to an area industrial facility helps students to see the transition of fundamental biorefining and biofuels research to the economic marketplace. By interacting with local companies, REU students gain a broader understanding of the growth of the renewable energy industry and research career fields. A principal goal of the C2B2/NSF REU program is to educate students about cross-disciplinary problem-solving teams which are better equipped to develop large scale renewable energy and product solutions for the world-wide deployment of engineering innovations.

Weekly group interaction is encouraged despite physical distance via videoconference seminars. By taking advantage of this technological interface, students learn from professional researchers at all four institutions. Videoconferencing provides students with a professional cyber-learning atmosphere and encourages participants to engage in research collaboration beyond traditional geographic barriers.

*Goal 3: Train students in the skills and knowledge needed to conduct research* – Throughout the 10-week REU Program in Biorefining and Biofuels, students attend a minimum of six (6) one-hour seminars as a group at one of the four research sites and engage in the remainder of the seminars via videoconferencing technology through his/her assigned research institution. Seminar topics are aligned by program administrators and are specific to the field of biofuels and biorefining, and are designed to teach other important research practices including laboratory safety, writing and presentation techniques.

Students share their research in a peer presentation forum which enables students to practice communicating research results. Students provide an overview of their research progress to peers, seek feedback on methods of overcoming research challenges and obtain peer suggestions towards improving presentation effectiveness. This seminar not only helps to strengthen student understanding of complimentary, and in some cases contradictory peer research, but also enhances peer relationships and provides a friendly venue to prepare for the culminating poster competition. The poster competition occurs during the final week of the program. Each student presents his/her research to faculty, postdoctoral and graduate researchers; a panel of faculty provides a critical and constructive evaluation of the poster presentations at this event.

*Goal 4: Recruit a competitive and diverse group of undergraduate students annually from across the country* – A principal objective of this site program is to encourage promising students, particularly women, underrepresented minorities, and students from primarily undergraduate

institutions, to pursue careers in engineering and science research. This program is specifically designed to reflect the cross-disciplinary and cross-institutional nature of modern research, especially in renewable and sustainable energy. REU staff coordinates recruiting efforts with administrative offices at each partner institution and maintains a database of contacts at universities across the nation.

## **Method**

Twenty students participated in the study. The average GPA of the twenty program participants in 2010 was 3.84. These students represent a wide range of prior laboratory experience with only 11 students having worked in a laboratory. Participants included 9 women (45%), 3 students from underrepresented minority groups (15%) and 3 international students (15%). Nineteen of twenty students were from out of state representing 16 different universities. Fifty percent of students were chemical engineering majors with the rest comprising seven other majors. Data was also gathered from 28 project mentors who were faculty or graduate students assigned to oversee student projects.

A mixed-methods methodology was implemented to assess the program with a variety of qualitative and quantitative methods. Quantitative methods include a pre and post-content test to assess learning of research methods, a student post-program survey to assess program outcomes, and a student mentor post-survey to provide an alternative perspective to student self-reported information. Content questions were solicited from presenters of the seminars. The questions were structured in a multiple choice format. Both the student post-program and mentor survey were developed from the program objectives. These surveys included Likert-type questions constructed with responses choices ranging from one to five with five often equal to “strongly agree.” Open-ended questions were also included for written feedback to better understand quantitative results. Qualitative methods included a mid-program focus group conducted with students at each site as well as a post-program structured interview. Both the focus group and interview questions were tied to program objectives.

## **Results**

Findings will be summarized below under each goal:

*Goal 1: Engage students in fundamental investigations of converting biomass to fuels and chemicals* – For this goal, assessment was focused on student engagement in their projects and students’ future plans for engagement after the REU program. Regarding project engagement, 100% of students reported obtaining useable results from their projects, 95% were able to fully articulate the nature of their project and its relation to biofuels research, and 85% of students reported a positive research experience. Mentors were also asked to comment on project engagement and 100% rated the project as appropriately scoped for the 10 week program. One

mentor commented, “I feel that (student) made great progress throughout the summer and I'm very satisfied with the amount of work accomplished.”

Suggestions for improvement to the projects included 30% of students who wanted better project planning at the beginning to be able to hit the ground running and 25% of students who wanted a more challenging project. One student commented, “My project also didn't really pick up til the last couple of weeks we were here so it was difficult to get poster and paper completed.”

Students were also queried about their future plans with 95% leaving the program with an interest in future lab experience, 90% with an interest in attending graduate school, and 85% interested in a bioenergy career. These findings were confirmed on the mentor survey where 80% of students expressed an interest to their mentors in future graduate work. One student commented, “This summer has been awesome! I have never done research like this before, so I really loved getting to be in the lab and get a feel for what research is like. It has really made me sure that I want to go to grad school.”

*Goal 2: Integrate the REU site to provide students with a collaborative, cross-disciplinary research environment* – Integration is a key goal with this REU program due to the participation of three state universities and one national laboratory in the Denver-metro area. Integrative efforts are focused in the academic administrative and social components of the program. Academic integration is focused on collaboration between the students and mentors within and between the labs at the four sites. While 95% of student felt well integrated into their specific labs, students were unable to articulate any knowledge about research going on at the other labs and the relationship of this research to their own.

Administrative integration is focused on satisfying the requirements specific to each campus (e.g., housing, lab access, payment). Administrative coordination and execution was managed by C2B2 staff (at the University of Colorado at Boulder, lead site). These requirements varied widely by site, requiring frequent inter-site communication among program points of contact at each site. A suggestion for improvement is to iron these out in advance of students’ arrival. One student commented, “find a more straightforward way to arrange payment of the stipend.” Social integration is focused on a social program and activities to build relationships between the students at the different sites. Results revealed that the majority of students were satisfied with each social activity, and reported they helped students connect with one another. One student commented on the social activities, “*Very well organized!!! Great fun side trips allowing for group bonding with people outside your institute. Concentrated activities in beginning to build friendships early.*”

*Goal 3: Train students in the skills and knowledge needed to conduct research* – Activities associated with this goal included weekly seminars and hands-on experience in research labs for students. The majority of students found each seminar useful with the bioplastics seminar rated highest (95% approval). Students expressed appreciation that seminar content was targeted for their undergraduate level. A suggestion for improvement to the seminars is to provide students

with greater training in the videoconferencing equipment so they can troubleshoot any problems that arise.

Mentors rated students' research skills in their labs. Ratings were made on a five point scale (1-5 scale, w/5 = Excellent) on nine research skills. Results indicated  $\geq 80\%$  rated as "good" or higher on eight of nine skills. The strongest ratings were for presentations skills (100% rated good or higher) while the weakest ratings were for writing skills (72% rated good or higher). One mentor commented, "(Student) is a very good researcher for someone at her stage. Although only on the project for a few weeks, she became conversant in the jargon associated with her project and was able to evaluate competing hypotheses specific to the field. She was at the level of an excellent first-year graduate student." Another commented, "(Student) made a significant contribution by synthesizing, for the first time ever, a new bioplastic copolymer. It is anticipated that this new copolymer will be useful in compatibilizing blends of bioplastics. These compatibilized blends may find use as new "green" carpeting materials." Mentors rated 50% of students' work as likely to result in publication.

Students were also assessed via a pre to post-program content test on research skills. Test questions were multiple choice and generated by REU program faculty and staff. Student content testing revealed significant ( $p < .05$ ) gains pre to post-test on student content testing. Table 1 below depicts the results of the t-test.

Paired Samples t-test		Mean	N	Std. Deviation
Pair 1	Pre-Test	69%	18	1.823
	Post-Test	79%	18	1.815
t	df	Sig. (2-tailed)		
-4.632	17	.000		

*Goal 4: Recruit a competitive and diverse group of undergraduate students annually from across the country* – The growing interest of this young population in biofuels and biorefining is evidenced by the continued increase in student applications to the program. Between 2008 and

Table 1: Research Skills Content Testing Results for REU Students

2010 the number of applicants has grown approximately 100% each year with 59 applicants in 2008, 122 applicants in 2009, and 237 applicants in 2010. The average grade point of the applicant pool remains relatively stable at a GPA of 3.4.

In two years of our self-funded pilot version of the REU site program, 9 of 59 applicants were accepted (15%) in 2008 and 19 of 130 applicants were accepted (15%) in 2009. The 2008 REU participants included 4 women (44%) and 3 students from under-represented minority groups

(33%). 2009 participants included 8 women (42%), 2 students from under-represented minority groups (10%) and 2 international students (10%).

The first year of the pilot program showed approximately one third of all applicants attending an in-state college or university. However, efforts to reach a larger pool of applicants resulted in only 11% of the 2009 and 2010 applicants attending in-state colleges or universities. This wide geographic range of applicants leads to a more culturally diverse group of participants, which in turn enhances the student's experience in the program. Another benefit to the students is that this program has no requirements regarding field of study. While the vast majority of applicants major in Chemical Engineering, forty one other majors were represented. This offers participants the opportunity to explore biofuels and biorefining research from different perspectives than they normally have in a classroom setting with peers.

Suggestions for improvement were provided by mentors who were concerned about the research qualifications of students. One mentor commented, "Perhaps try to ensure the REUs have some basic science under their belts prior to beginning summer research. According to (student), he had yet to take a general bio or general chem class in college." Another mentor commented, "Search for students not with a 4.0 GPA, but for students with research experience. Skills of how to mix simple solutions should be already present when student is entering the lab." These suggestions were born out quantitatively where students with previous lab experience outgained students with no lab experience on the content tests ( $p < .05$ )

## **Evaluation**

Assessment results were debriefed weekly with program staff and faculty during the program and at a summative debrief after the program. Overall, it was determined that the REU program recruited a diverse group of students, satisfactorily engaged students in research projects, posted quantitative gains in students' research skills, and integrated the program across four sites. Against these criteria, the program is judged a success.

Based on these evaluations, changes to the REU program were planned for next summer as well. Regarding Goal 1, student engagement, students will meet with their mentors at the beginning of the program to develop a project plan to assure consistent expectations and a quick start within their research groups. Regarding Goal 2, program integration, academic integration will be fostered by providing scripted tours and trained tour guides to host students from other sites in a tour of the different laboratories. Our hope is to improve student awareness of research at other sites than their own. Social integration will be enhanced by requiring all students to use on-campus housing to better get to know one another. Administrative integration will be improved with a formalized administrative support contact at each campus site.

Regarding Goal 3, student training, audiovisual training will be provided to students to allow for better broadcasting of seminars. Also, all seminars will be reviewed for relevance, quality, and content to ensure that topics match program goals and that presenters are matched to their area of expertise. Regarding Goal 4, recruiting, it was decided to forgo the results and suggestions to



select for research skills because of the desire to further broaden participation in biofuels research and include as many interested parties as possible.

## Summary

Undergraduate research is becoming a popular strategy for increasing retention of students in engineering. An undergraduate NSF funded REU program has been developed incorporating three state universities and one national laboratory within the Denver, Colorado metropolitan area. Twenty students participated in the most recent iteration of the summer program. The program was rigorously assessed with qualitative and quantitative methods. Results revealed achievement of a number of objectives associated with each goal as well as areas of targeted improvement for next year.

## Acknowledgement

This material is based upon work supported by the National Science Foundation under Grant No. 1005238. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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