Experience Developing and Implementing an NSF REU Site on Sustainable Management and Beneficial Reuse of Residual Wastes and Byproducts

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Abstract

The following paper summarizes recent experiences in designing and implementing a Research Experiences for Undergraduates (REU) site sponsored by the National Science Foundation (NSF). Faculty at California Polytechnic State University (Cal Poly), San Luis Obispo recently established the Global Waste Research Institute (GWRI), which provides unique opportunities for undergraduate students to participate in the advancement of fundamental engineering and scientific research. The GWRI provides the focal point of the REU program. The program, currently in its second year, supports ten students over a 10-week period during the summer. Faculty and graduate students serve as research mentors. The principal objectives of the program are: (1) to engage undergraduate participants on projects that provide opportunities for discovering new knowledge; (2) to mentor a diverse team of undergraduates; (3) to promote graduate study as a future professional goal; and (4) to provide instructive and appealing learning components. Undergraduates in the program attain three learning outcomes: design, conduct, and document a research experiment; function effectively on a multidisciplinary research team; and summarize both the technical and experiential aspects of the research experience. The program assessment plan and initial program results are discussed in the paper. The research team assessed and evaluated specific performance metrics defined under each outcome, where a performance metric represents a skill or ability that the undergraduate participant is expected to demonstrate by the end of the research appointment. Also included in the paper are short discussions on schedule and programming, professional development activities, student tasks/submittals, and mentoring. In addition, the paper provides a summary of research projects undertaken during the first year of the program.

Introduction

Faculty researchers at California Polytechnic State University (Cal Poly), San Luis Obispo recently implemented a Research Experiences for Undergraduates (REU) site sponsored by the National Science foundation (NSF). Positive experiences with undergraduate researchers supported through NSF REU Supplements motivated the authors to develop the subject REU program.[1,2] The new REU site, funded through the Global Waste Research Institute (GWRI) at Cal Poly, provides unique opportunities for undergraduate students to participate in the advancement of fundamental research related to wastes and byproducts. The institute provides the focal point of the REU program. A primary goal of the institute is to advance current practices in resource management. Ongoing research seeks to provide anticipatory solutions to the entire lifecycle of large quantities and wide varieties of wastes and byproducts generated in the U.S. and around the world.

The REU program, currently in its second year, supports ten students over a 10-week period during the summer. The principal objectives of the program are: (1) to engage undergraduate participants on projects that provide opportunities for discovering new knowledge; (2) to mentor a diverse team of undergraduates; (3) to promote graduate study as a future professional goal;

and (4) to provide instructive and appealing learning components. Undergraduates in the REU program attain three learning outcomes: design, conduct, and document a research experiment; function effectively on a multidisciplinary research team; and summarize both the technical and experiential aspects of the research experience.

The summer research appointments provide extensive time for research and discovery. However, specific periods are set aside for structured learning and professional development activities. These activities provide the undergraduates with tips, tools, and training to help them be successful in their research. Herein we describe how the summer program, student activities, performance measures, and assessment plan are linked to the program objectives and learning outcomes.

Participant Activities

The REU program consists of four parts: (1) pre-visit activities; (2) orientation; (3) research and professional development activities; and (4) post-visit activities. Table 1 summarizes the program schedule. Pre-visit and orientation activities prepare the undergraduates and mentors to succeed. Research and related activities represent the bulk of the proposed program and include weekly group interactions (workshops, field trips, seminars, and participant presentations) designed to improve communication, teamwork, knowledge transfer, and professional skills. Post-visit activities focus on assessment and broadening program impacts.

Pre-Visit Activities

We communicate with the undergraduate participants by e-mail during the weeks leading up to the summer program. An objective during this period is to match the participants with their research projects and mentors. The participants have opportunities to exchange ideas with project personnel, review project objectives, and finalize housing and travel arrangements.

Orientation

Orientation occurs over a one- to two-day period during the first week of the program. The undergraduate participants meet the research team members through a team building activity. The participants also tour the Cal Poly campus, library, and laboratory facilities. In addition, the faculty mentors outline their research projects, and the PIs describe the program objectives and learning outcomes.

Orientation also includes a series of interactive seminars and workshops on topics related to laboratory safety, research best practices, communication styles, and learning styles. Personality assessment tools (e.g., Myers-Briggs) help team members to understand one another and improve communication. Similar methods exist whereby individuals assess their own communication style, which is based on the degree to which the individual is assertive and outgoing.[3,4] As part of this REU program, participants and research mentors identify their own communication style by completing a self-assessment survey. The research team members then share and discuss their results during orientation. Participants also complete an Index of

Learning Styles survey.[5] Similar to above, the survey results are shared and discussed to enhance communication, teaching, and learning among the team members.

Table 1 - Schedule for the 2013 Summer Research Program

Week	Activities	Mtg.*	Description of Group Activities
Pre-Visit	Pre-Visit Assessment and Logistics	----	Participants complete surveys, indicate interest in specific research projects, and begin communicating with mentors
1	Orientation and Project Definition	W	Participants attend orientation workshop and prepare research plans with their mentors
2**	Research and Library Workshop	W	Literature review and library resource workshop with the Engineering Librarian
3	Continued Research	S	Waste management and landfill design/construction seminar with individual reflection exercise
4**	Continued Research and Presentation Workshop	W	Group meets for a workshop on effective presentation of data and research findings
5	Continued Research	F	Group field trips to the local wastewater treatment plant and Cal Poly Dairy Unit
6	Continued Research and Presentations	P	Participants present their to-date research findings during a group meeting
7**	Continued Research	F	Field trip to local landfill and recycling facility with individual reflection exercise
8	Continued Research	F	Field trip to regional landfill field test site and research facility with individual reflection exercise
9	Continued Research and Grad. School Workshop	W	Group meets for a roundtable discussion with current graduate students and discussion of graduate school
10**	Final Presentations and Reflection	P	Participants complete their research reports and present their findings; assessment surveys are completed
Post-Visit	Assessment and Follow-Up Communication	----	Final assessments are collected from faculty members and graduate students; participant progress is tracked through periodic communication

* - Type of group meeting: W = workshop; F = field trip; S = seminar; P = undergraduate presentations
** - Faculty mentors assess student performance and provide feedback via performance reviews

Research Activities and Professional Development

Successful research discovery requires the undergraduates to be engaged in their work. In developing this research program, we relied on our experience in planning, implementing, and assessing undergraduate research expereriences.[1] The program described herein (and summarized in Table 1) is designed to advance the students' skill sets and capabilities while also providing engaging professional development opportunities. Following orientation, the students work closely with their mentors to prepare a research plan. During subsequent weeks, the mentors lead 2-hour workshops designed to emphasize group discussions and activities. These

meetings provide the participants with the opportunity to exchange ideas, practice their communication skills, and address topics such as data analysis and presentation, report preparation, and graduate school. During the graduate school workshop, the participants begin drafting a graduate school application and purpose statement.

As noted in Table 1, additional group activities include field trips, seminars, and presentation meetings. The participants give presentations to their peers and mentors during weeks six and ten. These presentations are video-recorded and made available for the students to review. Faculty, graduate student mentors, and other attendees assess the content and delivery of each presentation and provide feedback to the authors. Briefly highlighting strengths and areas for improvement after each presentation allows for constructive and comfortable evaluations.

Post-Visit Activities

Participants complete post-appointment surveys. Faculty and graduate student mentors reflect on the program by completing a survey on student performance, research outcomes, program objectives, and program logistics. The research team reviews and evaluates assessment data as part of a continuous improvement process. As required, the team implements program improvements over the months leading up to the next program offering.

The project team maintains contact with the REU participants and tracks their progress after they leave Cal Poly. We use semi-annual e-mail correspondence to update the records and accomplishments of program graduates. In addition, the research mentors provide more regular guidance and feedback on post-visit presentations, publications, and graduate school applications.

Research Projects

The GWRI fosters collaboration among participants from the colleges of Engineering, Science, Agriculture, and Business. Experts from complementary disciplines within these colleges work together to develop innovative and sustainable solutions to existing and emerging problems associated with waste and byproduct management. Entrepreneurship is encouraged through various programs and projects. The GWRI has baseline funding (through 2018) and numerous externally funded projects supporting research and graduate students in three primary areas: pollution prevention and waste management; waste to energy conversion; and beneficial reuse of wastes and byproducts. These projects involve researchers and industry practitioners from civil and environmental engineering and related disciplines. Several of the investigations include multidisciplinary components, thus providing opportunities for undergraduates to work on technically diverse teams.

Table 2 lists ongoing or proposed projects associated with this REU program. During the first year of the program, undergraduate researchers participated in studies related to projects (1), (2), (3), (5), (6), (7), and (9). We do not provide detailed descriptions of the research projects in this paper. However, Table 2 defines undergraduate activities associated with each project, with each activity highlighted as high, medium, or low emphasis. As indicated in the table, the undergraduate activities cover an extensive range in terms of research program maturity level

(e.g., from devising experiments to interpreting and preparing results for dissemination). In addition, some of the available projects are longstanding investigations (up to 15 years) that provide undergraduates with unique perspectives on evolving and established research. Overall, the data presented in Table 2 are useful when defining potential research projects and matching projects with undergraduate student skill sets.

Table 2 - Nature of Undergraduate Student Participation in Research

■ - High Emphasis ● - Medium Emphasis □ - Low Emphasis

Example Research Projects	Undergraduate Activities (see list below)								
	a	b	c	d	e	f	g	h	i
(1) Engineering properties of wastes	■	■	■	●			●	■	■
(2) Bio-gas generation from algae biomass			■	■	●		■	●	■
(3) Thermal regime of landfills		■	●	■		■	●	●	■
(4) Corrugated fiberboard recycling	■	●	■	●	■				■
(5) Phytoremediation field and laboratory study	■		■	●			●	■	■
(6) Innovative beneficial reuse of byproducts	■	■	■	●	■		●	●	■
(7) Fuel ethanol production from food waste		●	■	●	■	●	■	●	■
(8) Recycled materials and byproducts in CLSM		●	■	●	●		■		■
(9) Field investigation of MSW landfills	■		■		●		■		■
(10) Gas emissions from landfill covers	■		■	●		●	●	■	■

a. Design experimental apparatus and procedures
b. Collaborate on experiments and analyses with other undergraduate researchers
c. Conduct laboratory or field experiments
d. Analyze data and develop correlations
e. Conduct parametric evaluations
f. Develop computer code for conducting numerical analyses
g. Compare experimental results to theoretical framework
h. Develop graphical presentation of experimental results for dissemination
i. Present research results in oral, written, and/or alternative presentations

Framework of a Typical Undergraduate Experience

The faculty research mentors work extensively with undergraduates on funded research and are confident in their ability to design and implement valuable and rewarding research experiences. Below we summarize a framework for the first project listed in Table 2. The investigation is typical of others carried out as part of this program: it includes novel research with engineering significance, complementary and comparative analyses, and multiple research attributes (laboratory, field, and numerical). In addition, the investigation promotes multiple interactions between student researchers, including undergraduate-to-undergraduate, undergraduate-to-graduate, and graduate-to-undergraduate.

Summarized are proposed research activities for the determination of specific gravity of municipal solid waste (MSW). Experimental determination of MSW specific gravity is

complicated by several factors including: large particle sizes, heterogeneous mixture of particles, relative specific gravity of individual particles with respect to water, complex particle microstructure, and potential interaction with water. The proposed investigation will include two undergraduates: Student 1 (S1) will conduct tests on manufactured fresh waste, and Student 2 (S2) will conduct tests on old wastes obtained from a landfill. A 10-week schedule for the project could include: (1) gather background information on specific gravity as input to the research plan; (2) identify existing methods for determining specific gravity and refine the research plan specifically for MSW testing; (3) assess the equipment available and determine the need for modifications and/or redesign; (4) continue equipment development (as needed) and prepare test specimens - S1 will prepare MSW specimens in the laboratory using published constituent composition data while S2 will obtain MSW specimens from the local landfill partner site; (5 & 6) conduct specific gravity tests as a function of constituent size and compaction (S1) and waste age and depth (S2); (7) analyze data; (8) analyze data and compare results obtained by S1 and S2; (9) assess influence of specific gravity on engineering properties - both students work with the graduate student mentor to investigate specific gravity effects on settlement using numerical modeling; and (10) complete a research report and presentation summarizing the test data, analysis results, comparative analysis results, and significance of the investigation.

Mentoring and Communication

We recruit graduate students to serve as mentors for the REU program. Ideally, we provide one-on-one mentoring opportunities between undergraduate and graduate students. If this is not possible, then we assign a maximum of three undergraduates per graduate student. Graduate students interested in serving as mentors provide a written statement of interest and a current CV in support of their application. We use these documents and interviews to evaluate the applicants. We provide graduate student with stipends to encourage commitment to the project.

Regular communication between the undergraduates and the mentors is essential to the success of this project. Organized activities and workshops take place during orientation to help facilitate teamwork and effective communication between the program participants. Faculty and graduate student mentors participate in the orientation workshops and work closely with the undergraduates as they prepare their research plans. Following orientation, the faculty mentors meet with their students at least once per week to discuss challenges and progress. Faculty-student meetings held during weeks two, four, seven, and ten include performance reviews where the faculty mentors provide formal feedback (positive and corrective) on work performance. Faculty and graduate student mentors also attend the presentation workshops to assess participant performance and provide feedback. In addition, we meet bi-weekly with the graduate students to review mentoring goals, discuss challenges, answer questions, and provide feedback on performance.

Weekly group activities are incorporated into the program to provide opportunities for the undergraduates to interact with one another, identify challenges, explore solutions to problems, and exchange ideas. Graduate students also attend these activities to interact with the undergraduates and provide mentoring. In addition, graduate students and faculty arrange occasional group social activities during the evenings and weekends throughout the summer. Group barbecues, pick-up sports, hikes, and other outdoor activities allow the undergraduates,

graduate students, and faculty to interact in a more relaxed and comfortable setting, which is important to young men and women thrust into a new environment away from their regular support network.

Program Objectives, Learning Outcomes, and Assessment Strategies

Table 3 lists the objectives of the proposed REU program along with assessment strategies and success measures. Table 4 lists learning outcomes for the participants. The outcomes articulate what the undergraduates are expected to learn during their research experience. Also presented in Table 4 are performance metrics and example learning opportunities. We define performance metrics as specific skills or abilities that we expect the undergraduates to demonstrate by the end of the research appointment. Learning opportunities represent tasks or activities that help the undergraduates to achieve the learning outcomes. The learning outcomes, performance metrics, and learning opportunities are tied directly to the assessment plan. Explicitly defining outcomes, metrics, and opportunities help faculty and graduate students to understand their roles as research mentors.

We use indirect and direct measures to support formative and summative assessments of the program and student performance. Measures include demographic information, pre-visit participant surveys, assessed student work (research plans, progress reports, final reports, presentations, and papers), periodic performance reviews, post-appointment surveys, tracking results for REU program graduates, and reflections by the mentors. To ensure consistency and reliability in program assessment and evaluation, faculty and graduate students use scoring guides and rubrics when assessing student work, conducting performance reviews, and interpreting survey answers. We are attempting to track and assess participant performance relative to each metric listed in Table 3.

Table 3 - Program Objectives, Assessment Strategies, and Success Measures

Program Objectives	Assessment Strategies	Success Measures - Did we succeed?
(1) Engage undergraduates on projects that discover new knowledge	Tally research publications and presentations prepared by program graduates and faculty mentors	Each year, at least 3 of the 10 program participants will co-author a conference poster, conference paper, or journal publication
(2) Mentor a diverse team of undergraduate student researchers	Tabulate demographic information for the applicants and participants	Each year, at least 6 of the 10 program participants will be recruited from underrepresented groups
(3) Promote graduate study as a future professional goal	Survey the participants on their understanding of graduate school; track program graduates through their early professional careers	Majority of participants will articulate the attributes of a successful graduate student; at least 50 percent of the program graduates will apply for graduate school
(4) Provide instructive and appealing learning components	Survey the participants before/after the program on learning outcomes; assess research plans, presentations and progress reports; conduct four performance reviews	All program participants will complete their research appointments; all participants will show improvement in technical and professional skills during the summer program

Table 4 - Learning Outcomes, Performance Metrics, and Learning Opportunities

Learning Outcomes	Performance Metrics (Demonstrate the ability to…)	Example Learning Opportunities
(1) Design, conduct, and document a research experiment	-Develop a research hypothesis and plan -Operate equipment and/or modeling software -Collect, analyze, and interpret test data -Document and report experimental test results	Prepare a research plan; work in laboratory; document activities; design or modify test equipment; work in the shop; calibrate and troubleshoot instrumentation; prepare charts and graphs
(2) Function effectively on a multi-disciplinary research team	-Behave in a professional and respectful manner -Accept and analyze feedback on performance -Articulate critical path issues for the project -Evaluate different communication styles -Apply active listening techniques	Participate in team meetings; manage a schedule; manage sub-tasks with technical staff; complete a communication survey; participate in seminars and workshops; participate in social activities
(3) Summarize both the technical and experiential aspects of the research experience	-List the primary objectives of the project -Describe the principal findings of the project -List the attributes of a successful graduate student -Describe a typical workday for a graduate student -Write an effective technical paper or report -Compose and deliver an effective presentation	Prepare progress reports; interview graduate students; present findings to mentors and peers; offer feedback on improving the program; co-author technical papers and reports; prepare research posters; prepare purpose statements for graduate school applications

Results from Year 1

During the first year of this project, we had less than 10 weeks to recruit and select our first team of summer researchers. Under this accelerated schedule, we prepared a program announcement and flier, advertised the program through various organizations, prepared an application, reviewed submitted applications, selected the undergraduate participants, and addressed various logistical items on campus (e.g. housing, meal plans, student identification cards, library and laboratory access, etc.).

We required interested undergraduates to request an application as part of the recruitment process. We required this first step to assess the students' written communication skills; to impress upon the students the formal nature of the solicitation; and to assess, in real time, the effectiveness of our marketing/recruiting efforts. When completing the application, a student provided his/her biographical information, transcripts, two recommendation letters, a current resume, and a written statement describing why he/she was interested in the research program. As part of this statement, the applicant was encouraged to discuss future goals and/or similar past project experiences, as they related to the research opportunity.

Table 5 summarizes recruitment numbers tallied for the first year of the REU program. As noted, we met or exceeded our target recruitment numbers for this first team of researchers. We

believe a smaller number of applicants resulted because of the short time frame available to advertise the program and select applicants. Indeed, some applicants decided not to apply to our program because they were already entertaining offers from other sites. For the second year of this program, we plan to triple the number of applications submitted.

Table 5 - Summary of the Recruitment and Participant Selection Process for Year 1

Parameter	Value
Number of applications started	110
Number of completed applications submitted	45
Number of female student applicants	21
Number of underrepresented minority applicants	13
Number of applicants from research-limited institutions	26
Low/average/high GPA for applicants	2.44/3.25/4.00
Number of participants	10 (target was 10)
Number of female participants	5
Number of underrepresented minority participants	3
Number of female and underrepresented minority participants	7 (target was 6)
Number of participants from research-limited institutions	5 (target was 5)
Low/average/high GPA for participants	2.92/3.42/3.91

We reviewed the four REU program objectives, given the results of the first year. Each of these program objectives were met, as summarized in Table 6.

Table 6 - Assessment of Program Objectives for Year 1

Program Objectives	Results	Objective
Engage undergraduates on projects that discover new knowledge	To date, participants have served as co-authors on one conference poster[6], four conference papers[7,8,9,10], and one journal paper.[11]	ACHIEVED
Mentor a diverse team of undergraduate student researchers	Five of the first-year undergraduate participants were female and three represented underrepresented minorities.	ACHIEVED
Promote graduate study as a future professional goal	To date, six of the participants have applied to graduate school. All of the participants demonstrated an understanding of graduate student attributes.	ACHIEVED
Provide instructive and appealing learning components	All of the participants finished their research appointments and demonstrated improvement in their technical presentation and reporting skills.	ACHIEVED

Each of the undergraduate participants completed an exit survey during the final week of the summer program. This survey included poll questions where participants assessed different aspects of the research experience as well as their own performance, rating questions where participants graded the value and conduct of the professional development activities, rating questions where students graded the administration of the program and the campus facilities, and open-ended questions related to various aspects of the program. Table 7 includes the poll questions included in the survey (with responses), which provides an example of data we collected during the first year of the program. It is noted that three of the open-ended questions on the survey included the following, as adapted from Sutterer et al.[12]

How does this summer REU program align with your short- and/or long-term goals as an aspiring engineering professional? (In this context, why did you want to participate?)

What specific aspects and/or outcomes of this summer REU program will be most helpful to you as you work toward achieving your short- and/or long-term professional goals?

What changes to this summer REU program would have made it more valuable in helping you to achieve your short- and/or long-term professional goals?

We used the survey as an indirect measure of our performance and the achievement of program objectives and participant learning outcomes. We noted areas for program improvement based an evaluation of these survey results.

We also assessed the participant learning outcomes by examining direct measures of student performance. For example, the participants learned about different personality types and communication styles during orientation. As part of an initial exercise, the participants evaluated their own communication style and guessed at the communication style of their faculty research mentor. We then "graded" the participants on their ability to evaluate the communication styles of others. The participants then evaluated the communication style of their graduate student mentors, incorporating feedback they had received from the research team. Based on the results of this exercise, all of the participants demonstrated improvement in their ability to evaluate communication styles.

As another example, we required each participant to deliver two formal technical presentations during the 10-week program. During the first set of presentations, the faculty and graduate student mentors graded each presenter on strengths, areas for improvement, and fourteen specific categories related to presentation organization, format, conduct, and technique. We summarized the presentation evaluations and provided a written evaluation report for each participant. We also provided each participant with a video recording of his/her presentation and the associated question-and-answer session. The participants reviewed their presentation reports and videos and self-assessed their performance prior to the second technical presentation, which they delivered during the final week of the summer program. We required the participants to incorporate improvements into the second presentation, based on the feedback received. All of the participants demonstrated marked improvement in their ability to develop and deliver technical presentations.

Table 7 - Example Survey Poll Questions and Results for Year 1

Read the following statements and indicate the degree to which you agree or disagree using the following scale: 1=Strongly Disagree; 2=Disagree; 3=Neither Agree or Disagree; 4=Agree; and 5=Strongly Agree.

Statement	Ave. Response
"Undergraduate coursework at my home institution prepared me for working on this research assignment."	4.1
"Undergraduate co-curricular and project activities at my home institution prepared me for working on this research assignment."	4.1
"There was a feeling of teamwork and cooperation on this research project."	4.3
"The research team (e.g. graduate students, faculty, and project investigators) at Cal Poly guided me in working on this research assignment."	4.7
"The research team members communicated project goals, objectives, and strategies."	4.4
"The research team members communicated research tasks and assignments."	4.4
"I sought to keep in regular contact with my research team members."	4.5
"The research team members provided me with feedback regarding my work performance."	3.9
"I accepted feedback from my research team members and sought to improve my work performance."	4.2
"The research team members treated me in a respectful and professional manner."	4.9
"The laboratory and field work environments at Cal Poly are safe and well-maintained."	4.2
"My technical skills and interests matched my research topic."	3.7
"I used online and library resources to thoroughly investigate the technical and scientific literature related to my research topic."	4.4
"I understood the critical path activities associated with my project and managed my time accordingly during the 10-week program."	4.4
"I regularly put in at least 40 hours/week of research work during this program"	4.0
"Overall, work on this project represented a challenging experience."	4.4
"Overall, work on this project represented an enjoyable experience."	4.4
"My research skills improved as a result of my participation in this program."	4.7
"Prior to this assignment, I was considering graduate school as a serious option after completing my undergraduate degree requirements."	4.2
"Because of this assignment, I am more seriously considering graduate school as an option after completing my undergraduate degree requirements."	4.0
"During the summer, there was a balance between research and professional activities (e.g. field trips, workshops, discussions, etc.)."	4.0
"I would recommend this research experience to a friend."	4.8

Areas for improvement

Based on the feedback from the research team members and participants, as well as the results of indirect and direct performance measures, we identified several areas to improve upon during the second year of the REU program. We summarize these areas for improvement below.

- During the first year of the program, we ranked the top ten applicants, based on a review of their application packages. These applicants were then assigned research projects and mentors based on project needs. To better match project needs and applicant skill sets, we are modifying this process for the second year. During this year, we will qualify 15 to 20 of the top applicants, based on a review of the application packages. Faculty research mentors will then meet and select ten final participants from this qualified applicant pool, matching applicant interests with specific projects and research needs. We recognized a need to improve in this area based, in part, on the scores shown in Table 7.

- We plan to assign research projects, faculty research mentors, and graduate student mentors to the undergraduate participants at least 30 days in advance of the program start-date. The goal is to provide the participants with reading materials and preliminary research training ahead of time so that they are better prepared to hit the ground running upon their arrival at Cal Poly. Such a goal should be reasonable, given the additional time available this year for recruiting and participant selection.

- In addition, we will use the extra time available during the pre-visit period to survey the participants and have them self-assess various technical, leadership, and communication skills. This background knowledge probe will provide information on the undergraduate students' training and preparation, which will allow faculty and graduate students to customize their mentoring approaches.

- Mentor training represents an essential part of the REU program, and we plan to improve upon our approach during the second year. Prior to the summer, the faculty researchers and graduate students will further enhance their mentoring skills by participating in a "mentoring of mentors" workshop. During this meeting, the mentors will review communication and learning styles survey results. The mentors also will review the participant learning outcomes and develop plans for assessing student performance. In addition, a faculty member will lead group discussions on giving and accepting feedback, developing interpersonal rapport with students, running effective meetings, and mentor (and mentee) expectations. We recognized a need to improve in this area based, in part, on the scores presented in Table 7.

- In general, we underestimated the energy and work potential of the undergraduate students (i.e., we should have had higher expectations with regard to workload and reporting requirements). In addition, we underestimated the need for clear directions and the time required for training (i.e., we should have provided a more structured research experience to make efficient use of the limited research time available to the participants). We plan to improve in both of these areas during the second year of the program.

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