IMPLEMENTATION STRATEGIES FOR A LARGE, MULTI-INSTITUTIONAL REU PROGRAM AND KEY ACTIONS OF SUCCESSFUL SUMMER RESEARCH MENTORS

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Abstract

Summer research opportunities for undergraduates, such as those supported by the National Science Foundation’s Research Experience for Undergraduates (REU) program, can be critical experiences that help persuade students to pursue graduate work. Our team has been involved in the administration and assessment of a large, multi-year REU associated with one of NSF’s Engineering Research Centers (ERC) with a significant emphasis on Chemical Engineering. Because ERC’s are 10-year projects, we have thus far six project years of experience with running a large, interdisciplinary, multi-institutional REU program that has graduated 78 students since its inception. Here, we report on approaches to recruitment, project definition, placing and advising students, and assessing programs.

We also discuss our unique approaches to training REU mentors. Because of the relatively small cohort size associated with single programs (ca. 8 – 12 students typically), the existing literature regarding mentoring in these programs is fairly anecdotal in nature; we are unaware of any examples of hypothesis driven research exploring the factors leading to positive outcomes for REU students, nor of any regarding the qualities associated with successful undergraduate research mentoring. In 2013, we conducted a survey of over 100 participants in multiple REU programs at our institution, to explore the validity of several hypotheses we had regarding the importance of mentoring and the qualities that characterize good mentoring. We will report preliminary findings from that effort, which include evidence-based recommendations on factors that lead to participant satisfaction, and on approaches to successful mentoring.

Introduction & Overview of Best Practices

Since its inception in 2008, The National Science Foundation Engineering Research Center for Biorenewable Chemicals (CBiRC) has had associated with it a dedicated Research Experience for Undergraduates (REU) site. With CBiRC’s formal launch occurring in the fall of 2008, the first cohort of REUs interns were hosted by CBiRC labs in the summer of 2009, and the total number of program alumni now
stands at 78. Contingent upon continuing funding, up to an additional 36 students might graduate from the program before project year 10. Furthermore, during the span of the CBiRC REU, the majority of our author team have been involved in the direction, administration, and/or assessment of two other summer internship programs at Iowa State University – one USDA funded, the other a separate NSF site – together serving an additional 64 students since 2011. The significant load of students through our programs offered ample opportunities to refine our approaches to serving participants, and many of the challenges and successes in the CBiRC REU were echoed in the other two programs.

Over the years, we have developed a series of best practices that have improved the quality of the student experience of our program participants, as well as of the faculty principal investigators (PIs) and graduate students who do the bulk of the day-to-day mentoring of the REU's. This paper describes some of the most important of those practices, and also presents results from our efforts to understand how mentoring impacts REU experiences.

Our best practices can be subdivided broadly into the following areas, here presented roughly chronologically through one year of the REU cycle: Do project level recruiting; Use a web-based application portal; Implement a hybrid selection approach; Conduction phone interviews prior to making offers; Mind the logistical details; Deploy a podcast-based mentor training program; Provide context, expectations, and opportunities to build community; and finally, Implement a robust assessment and evaluation program.

CBiRC’s faculty and research transcend the discipline of chemical engineering, but chemical engineering is at CBiRC’s core, and the other disciplines associated with CBiRC are closely allied to chemical engineering, e.g., chemistry, biochemistry and molecular biology, bioinformatics, agricultural and biosystems engineering. The centrality of chemical engineering to CBiRC motivated the presentation of this work at the AIChE meeting.

**Best Practices: Do Project Level Recruiting**

As with any educational endeavor, the abilities and motivational levels of incoming students is a critical factor in the program’s success. To attract a diverse pool of qualified and motivated applicants, we begin by soliciting potential research project opportunities from CBiRC labs. These opportunities are communicated to us by principal investigators (PIs), in the form of a short project title and two-sentence description. This step is critical in the operation of any REU (or other summer research) program that offers options that reflect a wide range of disciplines, even when these disciplines share some degree of commonality. This is because it enables students to have an inkling of the nature of the work that they may be doing, and allows us to ask that they articulate, in their applications, how they see themselves contributing to the project that they’ve identified as most interesting to them. This in turn assists with both evaluation and final placement, and increases the likelihood that each participating student is highly motivated when they arrive for the program.
Participants are recruited nationally through a variety of channels, including: NSF’s ‘Search for an REU’ website, our own REU Project website; lists of students developed by ISU’s graduate college during their visits to multiple fairs and or colleges that serve underrepresented populations; and direct communication with targeted departments across the nation including regional community colleges and other non-research-intensive higher-education institutions.

**Best Practices: Use a Web-Based Application Portal**

Having populated the program website with descriptions of specific projects, we require applicants to list their top three projects. That information is on their application form, which accompanies a personal narrative (that includes past research experience, current research interests, and long-term educational/career plans), undergraduate transcript, and two letters of reference, all of which are submitted electronically through a system we have developed in conjunction with the ISU College of Engineering Information Technology Services unit. Using this system avoids the challenge of tracking potentially hundreds of e-mail messages containing various portions of each application. The system we use allows recommenders to directly provide such letters, thus avoiding the awkward and undesirable situation of applicants handling (and potentially reading) their own letters of recommendation.

**Best Practices: Implement a Hybrid Selection Approach**

Once the application deadline has passed, we do a central (programmatic level) screening to identify 3 – 6 strong candidates for each open research project. Lab PIs then receive full packets for this subgroup of students and review and rank those candidates. The project director then makes the final selection for each lab based on PI ranking and programmatic needs (e.g., diversity of school of origin, etc.). It should be noted that PIs can rank any candidate as unacceptable, and if that occurs we will not place that student in that particular lab. We appreciate that labs are making a significant resource commitment to host an REU student, and a placement that is not desired by the PI serves neither the student nor the overall goals of the project.

**Best Practices: Conduct Phone Interviews Prior to Making Offers**

With the short list of candidates selected, it is important to begin making offers rapidly, for multiple reasons: First, there is a high demand for well-qualified REU candidates, and programs that delay the decision process risk losing good candidates to other opportunities. Second, but equally important, is that finalizing the cohort precedes making travel and housing plans – logistical details which for a large REU cohort are non-trivial! We have instituted a short phone-interview of all prospective participants prior to making a formal offer. This brief (ca. 10 minute, 4-question) interview is conducted by the program director, typically in the evening, and is not a
surprise – we first e-mail candidates to let them know they are finalists but that we would like to phone interview them prior to making formal offers. The goal of the interview is to get a sense of personality of the candidates, and more importantly to establish the program expectations before a formal offer is made. In particular, the phone interview emphasizes the importance of collegiality with the cohort and lab members, as well as commitment to helping the lab achieve its goals. Since instituting this step, we have had far fewer instances of personality conflicts within the cohorts. **Note – because this article will be publically available, and because we will be continuing to run this program for several more years, we do not wish to include the questions herein. However, any PI interested in the list of questions is welcome to contact the lead author who will provide them via e-mail.**

**Best Practices: Mind the Logistical Details**

Although perhaps fitting into the category of “too obvious to mention” we have found that it is easy to underestimate the volume of logistical details associated with a 12 – 15 student REU cohort, especially one where four or five students will spend most of their 10-week program at an institution far from the director and administrator of the program. And it is hard to overestimate the importance of getting the logistical details correct, from a student perspective. If not attended to, issues such as housing being ready when students arrive, travel plans being straightforward and negotiable by inexperienced travelers (as are many students from lower-resource backgrounds), and stipend checks arriving in a timely manner, can severely detract from student overall experiences. And if these problems are widespread (e.g., not just one or two students who perhaps have complex travel arrangements due to starting locations), it is possible for an entire cohort to sour on project leadership – we had a close call with this in one year and have heard from students in other projects where this has occurred – it is a situation best avoided through judicious planning! In our experience, having a faculty member (director) in charge of logistics does not work well at all. Typical faculty members associated with REU (and similar) programs have a multitude of other tasks as part of their core job responsibilities, and the heavy lifting of logistical details occurs throughout spring semester and particularly heavily in the latter half of that semester, which at many academic institutions is a time packed with other departmental, college, and university level activities in which faculty members are expected to participate. We have always found ways to fund – either through the program funds or through salary saving – approximately one quarter-time staff member per REU program, and this has been central to our success in keeping up with the logistical efforts required for these programs.
Best Practices: Deploy a Podcast-Based Mentor Training Program

Although mentoring, like teaching, is a skill that some seem to possess innately, it is too critical a function to leave to chance. This is especially true in highly research-active labs in which mentoring is most often done by a graduate student, post-doc, or other non-faculty member, and where that person may only spend one year in that role: it is often persons with low-experience mentoring to whom the REU student is assigned. We realized, after several years of operation, that our program would benefit from some form of formalized mentor training. CBiRC-affiliated labs, like many labs associated with strong NSF-funded Engineering Research Centers (ERCs), are highly research productive and are working to meet project-based targets. To respect the time constraints on these labs – which have already committed the time needed to take an REU – and to handle the multi-institution nature of our REU program, we wished to develop mentor training that could be delivered rapidly and at a distance. To that end, in 2012 we developed and delivered a podcast for REU mentor training (this was updated in 2013, and used in both 2013 and 2014). We requested that mentors, who are generally graduate students and post-docs generally, view the 13-minute podcast and then attend a face-to-face and electronic (for offsite mentors) discussion about mentoring approaches. Our mentoring approach is described in detail in a following section, but judging by the nature of the conversations that occur in the follow-up discussion session, this approach is increasing the awareness of mentoring key-actions, and is causing mentors to reflect far more on their role in the REU.

Best Practices: Provide Context, Expectations, and Opportunities to Build Community

As mentioned previously, we set some expectations during the brief phone interview process. Participants typically arrive on campus on the afternoon of Wednesday immediately after Memorial Day. This schedule works well for all except some quarter-system academic institutions. We typically identify one or two participants who are from our institution (the vast majority are from other institutions) to serve as local hosts with the understanding that they will help orient the visitors to our campus. These local hosts are normally embedded in the same housing with the other students, and are there on the day that the other students arrive. We also have the director and administrative lead visit the dormitory in which the students are staying to welcome them on the night that they arrive. The following morning, we begin with a breakfast followed immediately by the intake assessment – we do not want to contaminate our pre-experience data with any of the conversations that come later on the first day. After the intake assessment, we formally welcome students to the REU site and introduce them to the PIs, other faculty mentors, graduate students, and fellow REU participants. An introductory presentation describes the overall theme of the REU Project Site and its relevance, providing context for their work. The goals and logistics of the REU program are presented, as are our hopes and expectations for the program – this includes a discussion of the importance of contributing to the lab and to building community in the cohort – we are great believers in providing unambiguous
expectations. Students participate in general safety training during orientation also, although all labs provide additional specific training as needed. We also leverage non-federal funds to allow participants to go on a team-building event, typically a canoe trip down a local river, on the first Saturday of the program. On the next day (Sunday), we typically have the off-site students travel to their labs at other CBiRC member institutions ranging from 300 to 2000 miles away; the formal lab experiences begin on Monday.

Throughout the summer the entire cohort participates in weekly meeting with the program director. We use web-conferencing software to allow off-site students to participate, and these 30 – 45 minutes meetings allow an opportunity for progress updates, questions, and concerns to be discussed amongst all. We provide a poster template during week 1 and encourage students to begin building their poster immediately – for example, it’s often possible to provide a working title and authors, along with rationale, by the second week. Materials and methods can often be drafted by the fourth week, and so on. In fact, we have found that students can use development of the posters as a catalyst to move their projects forward or to clarify key concepts. We have also found that the weekly meetings – and the 3-day orientation – seem to be sufficient for the cohort to maintain a reasonable level of cohesion throughout the summer. And after complaints in the second and third program years about the off-site students missing out on the camps-wide REU poster session (which attracts well over 100 posters typically), we have budgeted for and had all participants come back to campus two days before the end of the program, so that the entire group is reunited and participates as a single cohort in the campus-wide poster session.

**Best Practices: Robust Assessment and Evaluation**

From the program outset with have contracted, and worked closely with a third-party educational assessment and evaluation team (the Research Institute for Studies in Education – RISE) based at our home campus. The assessment instruments were developed collaboratively, and include a written pre-program assessment given first thing on the morning of the program start, a written post-program assessment given immediately after the campus-wide REU session, a cohort-wide focus group conducted after the campus-wide REU session, and a written 6-month post program survey. In early years, we also had a mid-program written survey, but concerns about survey burnout and the limited value of those data in such a brief program caused us to drop that portion of the assessment and evaluation program. The anonymous results of the surveys and focus groups are summarized by RISE, and we have used these results to better understand and improve the program, and well as to illustrate some of the program’s impacts to NSF and to our peers.

**Mentoring Impacts**

Based on our research team’s experience in overseeing and assessing multiple cohorts of summer undergraduate REU participants, we developed a set of hypotheses
regarding key actions that typify good mentoring. In some cases, the hypothesis were
driven by negative examples; that is, we considered cases where an internship had
gone poorly and reflected on the mentor actions (or lack thereof) that contributed to
the problem. The six key components of effective mentoring hypothesized were as
follow:

- **Safe**—effective mentors teach students about laboratory procedures and safety
  protocol.
- **Prepared**—effective mentors are ready for their REU students – they have the
  necessary supplies and equipment and have ideas or a plan for the student’s
  research project.
- **Proactive**—effective mentors monitor the student’s progress and make meaningful
  changes when problems arise.
- **Patient**—effective mentors are patient and understanding with students.
- **Present**—effective mentors are readily available for students to approach, seek
  advice, and ask questions.
- **Positive**—effective mentors maintain a positive attitude in the lab and giving the
  student positive feedback on his or her work.

To examine the validity and relative importance of these six components of
mentoring, we conducted a survey of over 100 participants in REU programs at our
institution in the summer of 2012. The survey completed by each student consisted of
four sections. In the first section, students were asked who served as their primary
mentor (e.g., faculty member, graduate student, postdoctoral research associate, etc.),
how many contact hours they had with their primary mentor, lab PIs, or other members
in the lab group, and to indicate the value of various REU program activities (e.g.,
hands-on experience in lab, mentoring by faculty members, poster development, etc.)
using a 7-point Likert-type scale anchored by 1 = *not valuable at all* and 7 = *very
valuable*.

The second section of the survey focused on an assessment of students’
REU experience. Specifically, students were asked to report their level of agreement
ranging from 1 (*strongly disagree*) to 5 (*strongly agree*) with statements indicating
whether their experience influenced their decisions to pursue graduate school and/or
feeling that they made intellectual contributions to research in their respective host
labs. Two questions asked whether students are or will be coauthors on a published
paper and/or paper presented at a professional meeting. Using a 5-point Likert-type
scale ranging from 1 (*poor*) to 5 (*excellent*), students were asked to rate the following
REU experiences: laboratory experience, mentoring, social experience,
seminars/lectures, tours, and overall experience. Students were also asked to rate the
quality of their relationships with their primary mentor, lab PI (if different than primary
mentor), and others in their lab, using a 5-point scale ranging from 1 (*very poor*) to 5
(*very good*).

The final section of the survey was comprised of the 29-item Dimensions of
Mentoring Scale (not shown here for reasons of space). The items on the scale were
developed to assess students’ attitudes towards mentoring along the six dimensions
previously described. For example, questions were related to safety (e.g., my mentor
emphasized the importance of lab safety), preparedness (e.g., clear laboratory protocols and techniques were provided to me), presence (e.g., my mentor helped me become familiar with the tools and equipment available in the lab), positivity (e.g., my mentor gave me positive feedback on aspects of my work at least once a week), proactive behavior (e.g., my mentor stayed engaged in my project through the duration of the program), and patience (e.g., my mentor was patient and understanding when I asked questions). Students were asked to indicate the extent with which they agreed with each statement on a 5-point Likert-type scale ranging from 1(strongly disagree) to 5 (strongly agree).

The 70+ responses from the survey were then analyzed, with particular attention paid to the correlation between specific responses and the overall quality of internship experience. To summarize, all the dimensions of mentoring that were hypothesized were highly correlated with the overall REU experience at p values less than or equal to 0.01 (table below). Furthermore, second to the hands-on experience in the lab itself, mentoring was the most important single factor in predicting overall quality of experience.

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<th>Correlations (r) of Dimensions of Mentoring and Overall REU Experience</th>
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<td><strong>Dimension</strong></td>
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*Note: N=66; Bold indicates correlations with significant \( p \)-values, **\( p \leq .01 \)

**Conclusions**

We have presented here a series of best practices for running summer research internship programs, developed through experience with over 140 summer interns during the past six years. These practices address REU programs from the stage at which projects are sought from participating labs, to the stage at which program evaluation occurs. They address recruitment, application, participant selection, logistics, mentor training, setting expectations, and conducting assessment and evaluation. We hope that readers find these ideas useful in their own programs, because the deployment of successful REU programs (and similar) is a tremendous opportunity to build human capital and to further human knowledge through research – the practices here seek to increase the likelihood that these overarching goals are in fact met by the program.