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Computational Bioengineering Summer Research Experience for Undergraduates: Launching an REU Program during a Pandemic

Edward Sander (Associate Professor)

Dr. Sander is an Associate Professor in the Roy J. Carver Department of Biomedical Engineering at the University of Iowa, with secondary appointments in Chemical and Biochemical Engineering and Orthopedics and Rehabilitation. He is also the Director of Graduate Studies and the Director of the University of Iowa Computational Bioengineering NSF Research Experience for Undergraduates. Dr. Sander combines experimental and computational methods to understand how physical forces and mechanical environment contribute to the mechanobiology of tissue remodeling, particularly with respect to fibrotic tissue formation. He obtained his BS in Chemical Engineering from the University of Texas at Austin in 2000 and his PhD in Biomedical Engineering from Tulane University in 2006. He was a postdoctoral fellow at the Universities of Minnesota and Cincinnati before joining the faculty at Iowa in 2011.

Joshua Lobb (Assistant Director of Graduate Programs)

James A Ankrum (Associate Professor)

Nicholas A Bowman

Solomon Fenton-Miller

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Introduction

New computational methods, tools, and models are urgently needed both to improve human health and to understand the molecular, biochemical, and biophysical principles of life. Such advances are needed to provide early detection of disease, design new drugs and medical devices, and recommend better therapeutic strategies [1, 2]. These efforts are most likely to succeed when a collaborative team with diverse backgrounds and experiences converges on a problem [3-5]. To facilitate such diversity, we have established an REU on the theme of "Computational Bioengineering" to provide undergraduate students, particularly women and underrepresented minorities (URM), with a meaningful and authentic research experience at the intersection of engineering, medicine, biology, and computation, and in an inclusive multi-disciplinary team environment. Although the proportion of URMs that begin college as STEM majors has kept pace with national demographics (33%), only about 22% and 9% of science and engineering bachelor's and doctoral degrees, respectively, were earned by URMs in 2016 [6]. Additionally, only 20% of URMs in STEM complete their undergraduate degree compared to 40% of white and Asian students [7]. In engineering, the lack of diversity is even more apparent. In 2018, under 22% of engineering degrees were earned by women and less than 16% by Hispanics and African American students [8]. These numbers clearly indicate that more needs to be done to attract and retain women and URM students so that academia and the STEM workforce is more diversified.

The idea of providing *inclusive environments* is gaining traction as an effective tool for improving student retention in STEM fields [9, 10]. Inclusive environments are environments where an individual believes that those around them respect and value their background and training because it provides a unique and creative perspective that leads to better solutions. Research experiences with well-defined projects and high-quality research experiences are also key to maintaining student interest and persistence towards research as a career [11]. Many college students, however, including URM and first-generation students, attend two- and four-year institutions where access to meaningful research experiences are limited. By providing such experiences in an inclusive environment, these students will be more motivated and better positioned to attend graduate school and become part of the STEM workforce than if they proceed along their normal education trajectory.

To accomplish this goal, we started an REU program with the following objectives:
(1) encourage participation of students from institutions with limited research opportunities, particularly students from URM populations and from two- and four-year colleges.
(2) provide an inclusive and immersive research experience for trainees to learn fundamental concepts of computational bioengineering and how to apply them to solve biomedical problems.
(3) enhance oral and written scientific communication skills to facilitate collaboration across discipline boundaries.
(4) instruct students how to conduct research ethically and responsibly.
(5) prepare participants to pursue graduate studies and careers in a STEM field.

In this paper, we describe our first-year experience running this program, lessons learned, and new practices we will implement going forward.

Methods

Recruitment Targets: All undergraduate applications were considered, with priority given to recruitment of rising sophomore and junior women and URM students, and from institutions with limited research opportunities. Program targets are ≥ 50% women, ≥ 40% URM, and ≥ 60% from schools with limited research opportunities.

Recruiting Strategy: To advertise the program, we produced a flyer that linked to the program website (Fig. 1). We then asked mentors and other faculty, including the Dean of the College of Engineering to broadcast the advertisement to their network via email, Twitter, Facebook, *etc*.

Figure 1. Program Flyer and Announcement Tweet

Application Process: Students applied to the program through an online form accessible from the program's webpage. Students supplied their name, sex, first-generation status, current undergraduate institution, major, GPA, email, citizenship, current class standing, and race/ethnicity. Additional information collected included plans after graduation and the names of two recommendation letter writers. For the first year of the program, the application due date was set to April 1, 2021.

Selection Process: Applications were reviewed by five REU affiliated faculty members, including the Director and co-Director. The panel consisted of two men, three women, and one URM. Applicants were scored by two faculty members with a rating of 5 for absolute best, 4 for very good, 3 for maybe, 2 for no, and 1 for absolutely no. Average scores were calculated and applicants were sorted for discussion, starting with the highest scoring applicant. The pool was further modified and reduced to the top 22 students, and then the committee agreed on a final ranking. Program invitations were sent out based on ranking. If a student declined the invitation, the next highest ranked student was offered a spot in the program. An additional Iowa undergraduate student was selected for the program from the applicant pool. This student was supported by funding from the Iowa Center for Research by Undergraduates (ICRU) and other funds in order to have a local liaison for the other students and to give one of our own students access to the opportunities of the program.

Mentor-Mentee Pairing: Once students were accepted into the program, they were asked to rank their top 3 choices for faculty to work with. Students had 14 different mentors and projects to

choose from. Due to time constraints from when the REU site was awarded, the Director assigned students to eleven of the program mentors based on optimizing choices.

Orientation: The orientation session was held on the morning of the first day of the program. The students, a subset of faculty mentors, the Director, co-Director, associated staff, and the Dean of the College of Engineering gathered in a classroom. Everyone introduced themselves, beginning first with faculty and staff. Next, the Dean gave a welcome address, which was then followed by a general program overview by the administrator and the Director. Additional topics covered included how to keep a lab notebook (each studied received an Iowa embossed lab notebook), university code of conduct, sexual harassment/assault and reporting procedures, and how to ensure a safe and respectful environment. Students then met with their mentors and dispersed. A welcome event hosted by ICRU for all undergraduate summer programs on campus was canceled due to concerns about COVID-19.

Curriculum Design: Three workshops were hosted each week as described below. Workshop materials and scheduling information were provided to the participants through the University of Iowa's online course website, ICON. All students were enrolled in the REU ICON course website, which also facilitated the positing of program announcements.

- Introduction to Computing Workshop: This 2-hour workshop was held each Tuesday at 10:00 AM in a computer laboratory and introduced the students to the basics of high-performance computing, Linux, Python, Machine Learning, and other elements of computing. Each workshop began with a lecture of general concepts and was followed by exercises and coding activities, usually involving Jupyter Notebooks. During the last three weeks of the program, this time was reserved for office hours to help students with their individual projects.

- Communicating Science Workshop: The ability to communicate science is critical to the success of any researcher. To jumpstart the student's training in this area, a weekly workshop on Communicating Science was given each Wednesday at 11 AM. The course content was adapted from a graduate level course to make it accessible to students who were new to research and new to reading peer-reviewed literature. There were two main deliverables for students, a poster they would present at the end of the summer and a 2-page IEEE-style abstract. Students were taught in interactive sessions how to structure a scientific paper, how to find and cite papers in the literature, how to make their writing flow, the importance of editing, how to visualize data, and best practices for presenting and discussing their work orally. All class exercises directly contributed to the student's completion of their poster and IEEE abstract and did not add any additional "busy work" to their schedules.

- Weekly Seminar and Journal Club Series: Every Thursday at 10 AM, students met for either a seminar or journal club. Faculty in Biomedical Engineering, Electrical and Computer Engineering, and the College of Medicine presented research talks and provided a journal article from their laboratory. Additional activities during this time included virtual participation in a conference session of the Summer Biomechanics, Biotransport, and Bioengineering Conference and professional development topics, such as a workshop on LinkedIn and networking, how to apply for graduate school, how to make a resume/CV, etc.

- Responsible Conduct of Research Training: Students registered for and took the Phase I online Responsible Conduct of Research for Engineers provided through the Collaborative Institutional Training Initiative (CITI Program). Topics included can be found in Table 1. Students emailed proof of completion.

Table 1: Responsible Conduct in Research Modules

Using Animal Subjects in Research	Collaborative Research	Mentoring
Research Involving Human Subjects	Conflicts of Interest	Peer Review
Authorship	Data Management	Research Misconduct

- Extracurricular Components: Due to COVID-19 safety protocols, most of our planned social offerings were cancelled. We did host a welcome picnic in a park for the REU students, mentors, graduate students, and collegiate leadership. We offered various outdoor games and provided food and beverages.

Abstract and Poster Session: We hosted a research poster showcase in the final week of the program to give the REU students an opportunity to present their summer projects as a capstone for the summer (**Fig. 2**). College of Engineering faculty, staff, and graduate students were invited to attend the poster session. Nine students from the Nanoscience and Nanotechnology REU program joined us to present their posters as well. At the conclusion of the poster session, a luncheon was held to give the directors an opportunity to give a formal sendoff, thanking the students and mentors for their efforts over the summer.

Mentor Training: Each faculty mentor participated in the 8-hour Iowa Mentor Academy (IMA) training program. The IMA mentor training program builds on the curricula that have been developed through the NIH funded National Research Mentoring Network (NRMN), a nationwide consortium that was established in 2014 to develop and implement evidence-based mentorship and professional development programming. Dr. Lori Adams NRMN-certified "Master Facilitator," lead the eight-module program (Table 2). Faculty participated in a weekly 1-hour seminar hosted over zoom.

Table 2: Iowa Mentoring Academy Curriculum

Module 1: Maintaining Effective Communication	Module 6: Promoting Ethical Behavior
Module 2: Aligning Expectations	Module 7: Promoting Professional Development
Module 3: Addressing Understanding	Module 8: Articulating Your Mentoring Philosophy and Plan
Module 4: Addressing Equity and Inclusion	
Module 5: Fostering Independence	

Program Assessment*:* The program was assessed through several approaches. The assessment team (which consisted of a higher education faculty member and a Ph.D. student) met with the Director before the program to discuss the assessment plan. The faculty member conducted a focus group with participating students during the eighth week of the program to ask about their perceptions of the program and offer concrete suggestions for improvement. The Entering Research Learning Assessment (ERLA) was administered to both students and mentors during the last week of the program to understand students' growth over time; open-ended items were also

provided to allow all participants to provide feedback. The assessment team discussed the findings with the PI. Although the identities of individual respondents were known to the assessment team (in part so that mentor and mentee perceptions could be compared directly), the results were shared in a manner that did not link participants' identities to their responses.

Follow Up Tracking: Students were asked to join the LinkedIn Group "University of Iowa Computational Bioengineering REU to facilitate future tracking. Emails with students are also planned.

Results

Ninety-five students applied to the program. 54% of applicants were male, and 46% were female. In terms of racial identity, 56 applicants identified as White or White Other, 16 identified as Asian, 6 as African American, 11 as Hispanic, 2 as two or more races, and 4 who did not identify.

Figure 2. Snapshots from the REU Poster Session in the College of Engineering. Students created posters on their work and then walked mentors, faculty, and other students through the details of their projects.

A total of 13 invitations were extended to the top ranked applicants – two applicants declined. Eleven students were selected for the program. Ten students were supported by the NSF and came from other universities and colleges, including two from HBCUs. An additional Iowa undergraduate was supported by ICRU and funds from the Roy J. Carver Department of Biomedical Engineering. This student served as an important link to the other students and helped quickly familiarize them with the inner workings of campus and Iowa City. Four students were rising seniors and seven were rising juniors. 64% of the participants were female, 73% were URM, and 36% were first-generation students.

The REU participants arrived on campus and were assigned individual dorm rooms on the same floor of the building. COVID protocols were implemented to maximize health and safety. After orientation, the REU participants quickly assimilated into their home laboratories and the schedule of the program. Students spent most of their time in their home laboratories.

To facilitate more personalized assistance with the computational workshop, between two and four faculty mentors were present for most sessions. One challenge for the workshop was balancing the breadth and depth of content. Although the feedback was positive for learning the basics of python, classification, and how to apply it to machine learning, other topics, such as personalizing the shell environment, were less impactful for many students. For the communication workshop, the small class size made it possible for the instructor to adapt the content and pace to meet the needs of the students. Feedback from the workshop was unanimously positive. For most students it was their first time being formally taught how to find papers, navigate a paper, structure their scientific thoughts, and how to tailor the presentation of data to support their message. The seminar/journal club series was also viewed positively. It also provided a forum for the students to communicate their experiences to the director. As detailed below in the assessment, several recommendations were noted that we will implement in year 2.

The Student and Mentor responses for the ERLA can be found in Figure 3. Most students reported moderate to good gains in all the testing categories. Similar levels of gain were noted by the mentors.

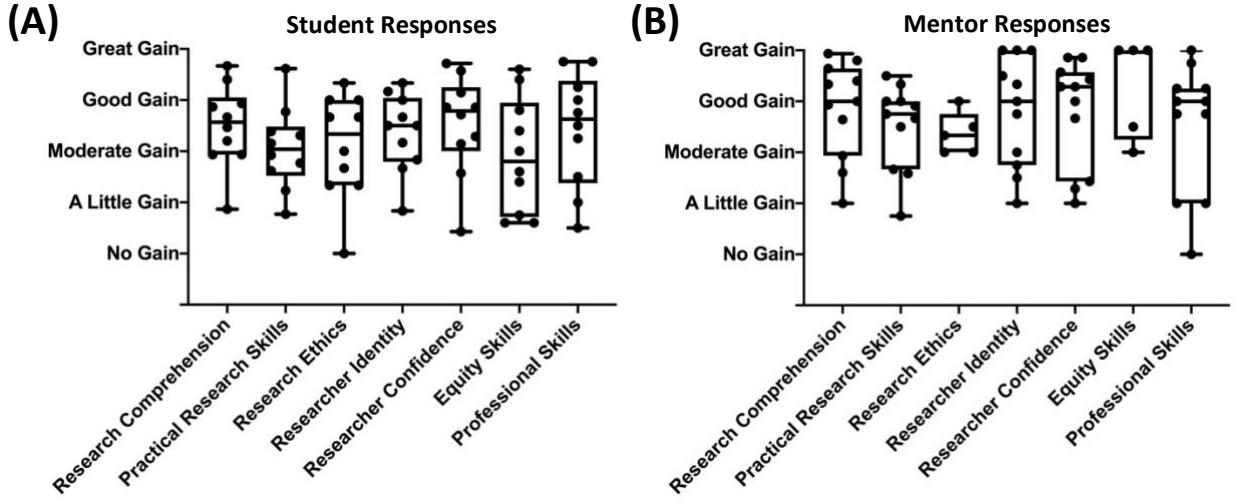

Figure 3. (A) Student and (B) Mentor ERLA Reponses

The focus group findings noted several positives of the program. First, the program fostered strong interpersonal relationships amongst the REU students. Workshop coordinators and graduate students in the host laboratories were noted as being helpful and attentive. Several mentors demonstrated a strong interest in the student and tailored the research project to meet their interests. In addition, having a local person who knows the area well was viewed as an important contribution to the overall REU participant's experience. Several specific workshop topics were

singled out as especially useful, such as writing, communication, machine learning, and journal reading. The ICON website was helpful for organizing information logically (i.e., PowerPoint slides, Python notebooks, articles for discussion, sample posters). Other positives included feeling that the skills learned were highly transferrable to different contexts, that the financial support was great, particularly the flexibility in spending it (with respect to food options), the quality of the dorm rooms, the welcome picnic, and the availability of nearby nature areas.

Several potential areas for improvement included setting clear expectations for mentors and students, ensuring the project descriptions used for recruitment are consistent with expected activities, setting expectations about engagement within and beyond the REU (whether summer courses are possible, whether workshop attendance is mandatory). Other comments for program improvements centered on improving communication and coordination with and among mentors, provide greater clarity in intended learning outcomes for each workshop. Also, it was noted that engagement with the Dean of the College of Engineering was highly valued, and that team-based projects could make the learning experience even better.

Additional outcomes from the program worth noting include a student abstract accepted for a presentation at the Orthopedic Research Society Meeting in Tampa, FL in 2022. Additionally, two of the four rising seniors in the cohort applied to and were accepted into the BME graduate program.

Discussion

In general, the first year of the program was viewed as a success by the participants and the mentors. We exceeded most of our demographic goals, although we did not attract as many students from institutions with limited research opportunities. We also found that the structure of the program was conducive to forging strong relationships among the participants. The participants and mentors both saw gains in the survey metrics from the REU experience. Based on the feedback received we have the following planned improvements:

- More advertising and recruiting of students from two and four-year institutions that provide limited research opportunities. Many of our Year 1 applicants came from institutions where research experiences can be found.
- More extracurricular activities will be organized for future REU cohorts, such as kayaking/canoeing, bowling, and attending Iowa City summer festivals as a group.
- The process for matching students to research mentors will be improved to allow the mentors more input into the matching process. This will give the faculty the opportunity to select the REU participants with the skill sets or interests that are best suited to their lab(s).
- We are working on a compact that lays out expectations for both mentors and for mentees. For example, REU participants must attend all scheduled events.
- REU participants will have more structured interactions with graduate students in our program through special panels and/or social events.

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