Board 200: A New Mentoring and Undergraduate Research Experience Model between REUs and RETs at the Stevens REU/RET Site Program on Sustainable Energy and Bioengineering

Dr. Patricia Muisener, Stevens Institute of Technology

Dr. Patricia Muisener is a Teaching Professor and Associate Chair of Graduate and Undergraduate Education in the Chemistry and Chemical Biology Department at Stevens Institute of Technology. She teaches and coordinates General Chemistry

Prof. Pinar Akcora, Stevens Institute of Technology

Pinar Akcora received her Ph.D. in Chemical Engineering at the University of Maryland-College Park in 2005. She completed her post-doctoral work at Columbia University between 2005-2008. She joined University of Missouri-Columbia, Chemical Engineering as an assistant professor in 2008 and has moved to Stevens in 2010. She is the recipient of the 2010 NSF-CAREER award and has received several grants from NSF-DMR, -CMMI and ACS PRF. She currently serves as the coordinator of the Nanotechnology Graduate Program and the PI of the REU/RET Site program (2021-2023) at Stevens.

A New Mentoring and Undergraduate Research Experience Model between REUs and RETs at the Stevens REU/RET Site Program on *Sustainable Energy and Bioengineering*

Abstract

The Stevens REU/RET Site project funded by NSF DMR program (Award #2050921) has completed its first two years and provided research and educational opportunities to both undergraduates and high school teachers. The program achieved its overarching goals with noticed improved mentoring, research experiences, and communication during the second year attributed in part to the in-person programming. The REU program aimed to create an experience that took students beyond the development of technical competence in science and engineering and provided an expertise particularly on research and innovation in various areas of energy and bioengineering. External evaluation, interviews and surveys of the REU and RET participants examined if the program goals were achieved. All teachers found the experience to be valuable and listed the people and the research environment as the two most impactful areas of the program. This paper will further discuss the specifics of this novel REU/RET program as well as the outcomes.

Introduction

An REU/RET Site project funded by NSF DMR program has provided research experiences for 14 REU and 6 RET participants in Chemical Engineering, Mechanical Engineering, Biomedical Engineering, Chemistry & Chemical Biology Laboratories of Stevens. 6 REUs and 2 RETs participated virtually the first year due to COVID-19 and 8 REUs and 4 RETs participated in-person the second year.

The goals of the REU/RET program were four-fold: 1. Create a vibrant research environment for all participants that offers the implementation of innovative ideas in sustainable energy and bioengineering. 2. Educate students to become independent researchers with entrepreneurial thinking skills and provide them opportunities to use their newly developed as well as innate skills in the summer-end final project presentation and competition. 3. Develop a network of mentoring relationship among high school teachers, faculty and underrepresented minority (URM) undergraduate students that will support them in their professional and graduate careers. 4. Educate teachers on sustainable energy and bioengineering and help them create their lesson plans for high school curriculum development on nanotechnology and engineering that will increase students' interest in STEM fields.

The program aimed to create an experience that took students beyond the development of technical competence in science and engineering and provided an expertise particularly on research and innovation in various areas of energy and bioengineering. Seminars and workshops complemented the program providing students skills in areas such as laboratory safety, literature searching, entrepreneurship, effective mentoring and research ethics. The weekly group meetings with the program PIs fostered interdisciplinary communication between REUs which strengthened collaborations. The community was further strengthened in the second year by incorporating more events with lab mates and students living together on campus.

The RET program was designed to allow undergraduate students to interact directly with high school teachers and assist in designing research-focused curriculum to motivate and excite students into pursuing STEM careers. A multi-level mentoring experience was created by pairing the RET participants with the REU students, faculty mentors and graduate students. RET participants joined 4 weeks before the end of the program. RET welcoming events were added to foster inclusion into the research environment. One

such event, REU science chalk talks, enabled both groups to ask and answer questions, creating a unique bond. Teachers were learning from the REU students which reinvigorated learning and teaching experiences for all. The program achieved its overarching goals with noticed improved mentoring, research experiences, and communication during the second year attributed in part to the in-person programming. This paper will focus on the methods to support undergraduate students evolving into scholars, mentoring and interactions between teachers and students, and outcomes.

REU Student Scholars

In the first year of the program, there were 6 students, all engineering majors, 5 rising seniors and 1 rising junior. There were 2 teachers, both teaching Chemistry, one from West Orange NJ and the other from New York City. In the second year of the program there was 1 rising sophomore, 5 rising juniors, and 2 rising seniors. 7 students were Engineering majors, and one majored in Biochemistry. Half of the students had no prior research experience. The teachers were all from the New York City area and taught a variety of subjects including Physics, Biology, Chemistry, Algebra, and Urban Ecology.

One goal of the program is to develop students into scholar's whose "knowledge is acquired through research, through synthesis, through practice, and through teaching"[1]. One framework for the educational goals of this program is the revised Bloom's Cognitive Taxonomy by Anderson and Krathwohll. In this revised model, *Create* category of knowledge is at the apex of the learning hierarchy and considered to be the highest form of learning, and defined as "Putting elements together to form a coherent or functional whole"[2]. Teaching, one form of creation, is considered to be one of the most difficult mental functions in the new taxonomy. Communicating knowledge to others can both facilitate and consolidate understanding[3]. The undergraduate students, especially during the second year of the program were empowered to teach both the other REU participants as well as the teachers (who joined the last 4 weeks of the program) focused lessons about their research. In both years, the weekly group meeting among the participants and program directors allowed each REU student to discuss their research in depth and provided mini lessons each week on their research. In year 2, we integrated both a "chalk" talk and a student led tour into the first week of the RET program. In the informal "chalk-talk" students used a marker board to draw out their research for the teachers. This informal 15-minute presentation allowed the students to talk to the teachers about their research and answer questions. These "chalk-talks" gave the teachers an opportunity to learn about the research and assist them in determining which lab they want to work in. Each student was responsible for walking the teachers through their labs and explaining all the equipment and experiments. All the students visibly enjoyed this opportunity, seizing the opportunity to show their research space. During the weekly presentations, all the students would clearly explain their research and would enthusiastically answer teachers' questions. In this REU/RET project, teachers were paired-up with the REU students and students took the responsibility to teach teachers about their project. This responsibility of teaching empowered the students within their research environment, synthesized their learning and helped them direct the learning of others. Taking responsibility for the learning of others can lead to deeper overall understanding[4] which we noticed in the students especially within the last few weeks of the program.

In the development of students as scholars, the weekly meetings and interactions allowed for depth of learning and ensured the development of communication skills in an environment conducive to scientific discussion and reflection. Research discussion meetings between students and teachers were monitored by the faculty mentors to enrich discussion and teaching. It was evident that the research discussions, which were in-person, were more intense in year 2 and involved all participants. In year 1, the virtual environment did not completely lend itself to discourse as easily as in-person. Also, in year 2 the students were able to

work directly with the teachers in the lab. The development of the REU participants and the connections between the teachers and the REU participants were deeper in the in-person programming.

Mentoring

In our program, undergraduate participants were paired with graduate students, RET participants and faculty mentors to create a multi-level mentoring experience that will enrich all participants. The first week of the program the students participated along with their graduate mentors in an effective mentoring workshop given by Dr. Wei Zheng in the School of Business. This workshop allowed the students to reflect on best practices in mentoring. The workshop was provided to the participants in both years of the program. During the virtual program, the only way for interaction between the graduate and undergraduate students, was through zoom and a virtual hangout. However, in year 2 the in-person nature of the program allowed for more formal and informal interactions, nurturing a stronger relationship. During the first week, the graduate student mentors paired with the REU students, participated in a panel. The graduate students reflected on what led them to graduate school and provided advice to the students on how to best approach the 10 weeks of the program as well as advice on research in general. The graduate mentors then took the students through a tour of the labs. This direct interaction on the first week of the program, allowed the students to feel more comfortable with the graduate students. The RET program allowed undergraduate and graduate students to interact directly with high school teachers and assist in designing relevant curriculum on materials for energy that will be employed in area schools to motivate and excite high school students into pursuing STEM careers. All participants and mentors in the program attended the REU Poster Symposium. This multi-layer mentoring approach allowed all participants many ways to experience a variety of viewpoints, learn and grow in research.

Research Support

The first week of the program for the REU participants consisted of an orientation which included safety, the library, research mentor introductions, meeting graduate student mentors and lab mates. Seminars were spread out throughout the 10 weeks of the program to provide enrichment which included literature searching and citations, inclusive teaching, developing effective mentoring techniques, research ethics, abstract writing, presentation skills, graduate school application and NSF graduate research fellowship program (GRFP). There were also Meet the Prof sessions in addition to faculty research seminars. During the second year of the program there were more in-person events including tours through labs such as the microscopy facility.

The program was structured to provide support for students to succeed in research. The students completed weekly reports to keep them on task and allowed them to track their progress during the 10 weeks of the program. Questions included in the progress report were:

- What did you do this week?
- What is/are your research question(s)?
- How have your research questions been developed or refined this week?
- How is the research methodology being developed and why it is appropriate?
- What literature did you find/explore this week and what was the most useful?
- What data was collected this week? (Feel free to attach a few pictures or graphs of your data at the end of this document.)

- Problems or potential problems this week?
- Questions or areas in which you need help to accomplish your research goals?
- Describe your overall progress for this week?
- How would you rate your progress on a scale from 0 to 10, where 10 is the highest amount of progress.
- What is your plan for next week?
- Paste pictures below of graphs or pictures or anything else you want to share from this week.

The progress reports were reviewed by the co-Directors and the REU faculty advisors. The progress reports combined with the weekly group meeting presentations allowed the students to self-assess and gauge their progress. The progress reports evolved over the course of the 10 weeks and indicated growth and learning for all students: both those that participated virtually in year 1 and those in-person in year 2.

The RET participants were tasked with creating a lesson plan based on their learnings. The first few weeks they attended workshops focused on curriculum development. A high school teacher with RET experience who mentored participants and led a workshop on brainstorming and collaborating; and a member of Stevens Center for Innovation in Science and Engineering (CIESE), worked with teachers on their lesson plans and provided a workshop series. The RET participants shared their lesson plans with a teacher network as well as created a poster on their curriculum to share with others.

Outcomes

All participants and faculty mentors attended the research symposium. The REU students presented posters on their research and 3 students used these posters to present at conferences in the Fall. The RETs presented their posters on their lesson plans they created. The RET participants saved their posters to share with their colleagues and high school students.

Through analyzing the REU students program reports, it was evident that the students gained confidence in research, and they progressed over the 10 weeks. The reports over the weeks contained more details of their work and less questions on how to do the project but more questions about their specific observations and data collected.

External evaluation and surveys of the REU and RET participants examined if the program goals were achieved. All teachers found the experience to be valuable and listed the people and the research environment as the two most impactful areas of the program. The students found the most significant outcome of the program was learning how to conduct independent research and they highly valued their faculty mentor's research instruction, mentoring, and supervision.

We plan to continue our REU/RET program in coming years and will submit our proposal to NSF. The Stevens REU/RET program is a good model to run a collaborative educational-research platform and we need to continue the program to show its impact. This will help us in preparing for large research center proposals such as MRSEC and ERC. In future, we hope to focus on research projects on sustainable energy and bioengineering within 2 departments: Chemical Engineering & Materials Science and Chemistry & Chemical Biology.

Summary

The interdisciplinary nature of the Stevens REU/RET program on Sustainable Energy and Bioengineering has implemented a unique mentoring experience between undergraduate students and teachers of the

program. The connection between the two groups was fostered through seminars, workshops, panels, group meetings, chalk talks and lab orientations. Teachers found *the people* and *the research environment* to be the most impactful components of the program. The program was found to be successful at creating the collaborative environment between students, faculty, and the teachers.

Acknowledgement

This work was supported by the National Science Foundation DMR program Grant # 2050921.

References

1. Boyer, E. L., Scholarship reconsidered: Priorities of the professoriate. *Lawrenceville, NJ: Princeton University Press* 1990.
2. Wilson, L. O., Anderson and Krathwohl–Bloom's taxonomy revised. *Understanding the New Version of Bloom's Taxonomy*. 2016.
3. Marvell, A.; Simm, D.; Schaaf, R.; Harper, R., Students as scholars: evaluating student-led learning and teaching during fieldwork. *Journal of Geography in Higher Education* 2013, *37* (4), 547-566.
4. McMullen, V. B., Using student-led seminars and conceptual workshops to increase student participation. *College Teaching 62* (2), 62-67.
5. Osterwalder, A.; Pigneur, Y.; Smith, A.; practitioners, Business Model Generation. *self published.* 2010.
6. Osterwalder, A., The Business Model Ontology - A Proposition In A Design Science Approach. *PhD thesis, University of Lausanne* 2004.