CUR Quarterly
COUNCIL ON UNDERGRADUATE RESEARCH

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Student Perspectives on Facilitating Positive Undergraduate Research Experiences

Following are the stories of three women who participated in summer Research Experiences for Undergraduates (REU) at different institutions, before or after an academic-year research internship at their home institution. Their experiences in 2010 led us to compile a set of recommendations for positive REU experiences. The recommendations should be useful for anyone participating in or coordinating summer research programs, including program coordinators, research mentors, and students.

Programs providing REU's have been shown to provide a wide range of specific positive outcomes, as well as an enhanced overall educational experience (Lopatto, 2004). Students report improved research skills within experimental design, data collection and statistical analysis, and an improved understanding of contemporary concepts in their fields (Kardash, 2000). REUs enable students to confirm or discover new career paths and gain confidence regarding graduate school (Gonzalez-Espada and LaDue, 2006; also see references therein). Faculty research supervisors and administrators of REU programs report that, as a result of the research experience, students are more likely to pursue advanced degrees and research careers (Floyd-Smith, 2008). Although REU programs are generally short-term, participants tend to walk away feeling that their research results contribute to the larger picture of their field (Kardash, 2000).

The summer research experiences of authors Sara Thomas, La'Toya James, and Monika Frazier took place at, respectively, the Monterey Bay Aquarium Research Institute (MBARI), the Woods Hole Oceanographic Institution (WHOI), and the University of Hawai'i (UH) Mānoa campus on the island of O'ahu. All those institutions are part of the National Science Foundation-sponsored Center for Microbial Oceanography: Research and Education (C-MORE).

Overview of Research Experiences

Sara Thomas, who graduated with honors from UH Mānoa in 2009 with a major in global environmental science, did her senior thesis on analysis of trace metals in soil cores. She worked with the Environmental Sample Processor (ESP) at MBARI under the supervision of scientist Julie Robidart in the summer of 2010. The ESP provides *in situ* collection and analysis of water samples from the subsurface ocean. Sara worked on two marine biogeochemistry projects using the ESP. The first involved designing DNA primers to target a specific gene in *Synechococcus*, an abundant unicellular cyanobacteria, and producing a phylogenic tree by sequencing grown cultures to ultimately identify the organism's evolutionary diversity in Monterey Bay. The second project entailed optimizing *nifH* molecular assays, which contain DNA primers for the genes that code for nitrogen fixation in certain marine microorganisms, and determining standard curves to allow ESP quantification of *nifH* genes in environmental samples.

La'Toya James, a senior biology major and honors student at UH Mānoa, plans to pursue dual MD-PhD degrees to combine her interests in clinical practice and research. During the academic year, she studies pathogenic bacteria in faculty member Grieg Steward's laboratory. At WHOI, she worked in the microbial biochemistry group under the mentorship of scientist Daniel Repeta, whom she had met in spring 2010 at the annual meeting of C-MORE institutions. Her summer research focused on the extraction and quantification of organic and inorganic phosphorus-containing compounds from seawaters locally and abroad. Through this project, La'Toya learned a wide range of new laboratory techniques, including ultra-filtration, rotary evaporation, spectrometry, resin preparation, time course experimentation, and solution preparation.

Monika Frazier, a senior in the marine science department at UH Hilo on the island of Hawai'i, plans to attend graduate school in the Tropical Conservation Biology and Environmental Science program at UH Hilo. During the academic year, she uses molecular techniques to identify the types of bacteria and archaea associated with the tissue of the coral *Montipora capitata* in scientist Misaki Takabayashi's laboratory. After spending the summer of 2009 at MBARI, where she worked on developing assays for the ESP aimed at identifying harmful bacteria, she conducted research during Summer 2010 at UH Mānoa Hawai'i Institute of Marine Biology (HIMB) off the island of O'ahu. Under the mentorship of scientist Michelle Phillips, Monika learned new molecular techniques to compare the levels of gene expression among healthy and diseased coral tissue.

Recommendations

All three students wrote reflections on their summer experiences and found that although they researched different topics at different locations, certain commonalities emerged. The following recommendations grew out of those shared experiences. Beneath each point is an excerpt from one or more of the students' reflections.

1. **Acknowledge the research "fear factor."** Students may be concerned about disappointing mentors by not having enough skills or knowledge, not being quick

enough to pick up new concepts, or asking dumb questions. Speak to students and mentors beforehand about each side's expectations and the importance of bravely asking—and patiently answering—questions.

Sara Thomas recalls: "I was nervous going into the summer internship because of my lack of experience and knowledge of microbial oceanography. I had only taken a semester of marine biogeochemistry and one year of basic biology; otherwise I had no experience in molecular laboratories or even classrooms. Furthermore, the ESP project is a prime example of MBARI's integration of science and technology, and I had no engineering experience either. What if my mentor, who earned her PhD in marine microbiology from the Scripps Oceanographic Institution, was expecting an intern who could dive right into learning about the revolutionary technological capabilities of the ESP, but instead discovered her intern needed to be taught basic molecular laboratory techniques?"

"While the morning of the first day was dedicated to touring the facilities, having directors welcome us, and learning the logistics and schedules, meeting Dr. Robidart at lunch was at the forefront of my brain. I was anxious because I felt like I had to confess that I knew nothing about the summer project/subject that I signed up for. I worried she would be disappointed and frustrated with me from the very first day. I didn't want her to dread the next ten weeks and feel like she had volunteered to baby-sit a recent graduate. I also didn't want to lie about how knowledgeable I was in the subject because then I wouldn't get anything out of the internship other than frustration and a plethora of botched experiments, which would ultimately reinforce the frustration from my mentor I so hoped to avoid."

"I was relieved when I met Dr. Robidart, because I felt that having a younger mentor would allow us to connect socially, and that she could relate to what I was going through. When I told her I didn't have a strong background in microbiology, she assured me that she remembered what it was like to be in the hot seat just starting out. This simple discussion calmed my nerves and reinforced the reason I was there in the first place, to learn something new. I'm also glad I addressed my concern early because I felt we established great communication from the start."

2. **Don't ignore the students' personal "fear factor."** Students may have concerns about spending the summer at a different institution, particularly if they live with their family or have limited travel experience. Discuss this openly and encourage students to ask questions. Be clear about what the students can expect (e.g., in terms of housing, costs, transportation, weather), as this knowledge may allay fears. Housing is a particular concern for students, and any efforts that can be made to arrange comfortable, convenient housing will be much appreciated.

Monika Frazier explains: "The Hawai'i Institute of Marine Biology is a laboratory located on a 26-acre island in Kāne'ohe Bay, O'ahu. I knew in advance that I would need to find my own housing during the internship period. Housing on the island is limited, and it was difficult to find an available room to rent in the area for such a short period of time. I feared that this meant that I would not be able to participate in the internship. Fortunately, housing became available on-island, and I was able to reserve a room for all but two weeks of my internship. I took this as a blessing and knew that I would figure something out for those other two weeks—the internship was on. It seems like a rash decision at this moment in time, but I wasn't going to let two weeks prevent me from going! I definitely would not have made the same decision if it wasn't in Hawai'i and if I didn't know so many people who lived on O'ahu, including my own sister. It later worked out that the class for which rooms were reserved was cancelled, and I was able to stay on-island for the entire duration of the internship."

Says La'Toya James: "The thought of venturing to the mainland United States seemed daunting. Although I have been an active researcher since beginning my college career, the idea of traveling alone and living with others for almost three months was not one that settled well at first. … This was my first time living away from my family. I was housed with five other female undergraduates from around the world. The housing arrangement at Woods Hole was comfortable and well suited for students. Transportation was provided for students to purchase food items and other necessities. The landscape of the town of Falmouth, Mass. allowed for easy hiking and cycling to the local shopping centers. Living with five strangers was not as horrifying as I had convinced myself it would be in the weeks before my arrival. Because each student was from a different part of the country or from another country, a sense of uniqueness brought us together. We learned to share the space which we occupied and to settle differences over minor issues such as unwashed dishes. Many of the local residents also made me feel welcome. They shared their knowledge on great places to eat, shop and relax."

3. **Use social networking tools beforehand.** Some REU program coordinators will ask interns' permission to share their contact information prior to the program. This can help break the ice and allow summer roommates to "meet" each other (e.g., on Facebook) ahead of time. Such contact information also lays the groundwork for continued networking after the program ends.

Sara Thomas explains: "The MBARI interns' 2010 Facebook page, set up by program coordinator George Matsumoto, was a huge success for 'breaking the ice' virtually among interns. I quickly discovered that my fellow interns were from all over the globe, including Australia, England, and India, and

that we all shared common interests. The intern cohort avidly posted their interests and ideas for the summer so we were able to plan activities before the internship even began. It was a relief to get a sense of the other interns before I left for MBARI since I would be in close quarters with them for ten weeks. Our Internet connection also allowed a smooth 'meet and greet' when we came together in California for the first time. I continue to stay well connected to those in my cohort through Facebook even though we are once again spread across the globe."

4. **Try to tie the summer REU project into research or coursework.** If summer work can be grounded in activity at the students' home institutions, students can more easily continue to develop and apply their skills during the academic year.

La'Toya James notes: "During my summer internship at WHOI, I acquired a new set of skills that I would later utilize in a course at UH Mānoa, my home institution. Working alongside Dr. Repeta, I learned to quantify phosphorus from large subsamples of seawater. Using the subsample and dilutions that had been made throughout the experiments, I was able to determine the concentration of phosphorus in our oceans. When I returned to UH in the fall, I faced a similar task in my biology lab, where we were asked to determine the number of bacterial cells present in a sample before it had been diluted and quantified. Most of the 15 or so students did not know how to go about solving the problem. However, I was able to apply the knowledge from my experiments at WHOI and easily complete the assignment."

5. **Don't start students off with high-risk research.** If the student's main research project is likely to fail, allow the student to spend some time on a different project that is likely to get more exciting results. This smaller project can help reinforce students' confidence, especially if they are expected to present research results at a symposium.

Sara Thomas recalls: "Toward the end of my internship, I was nervous about the intern symposium, where I was expected to present my research results. Although I had worked diligently throughout the summer, my primer design demanded more time before it could prove successful. I was uncomfortable presenting failed methods, especially since this was my first time working in a molecular laboratory. I was grateful that Dr. Robidart had the foresight—and the confidence in me—to allow me to handle two projects throughout the summer internship. The second project on optimizing *nifH* molecular assays yielded successful results. Together we mapped out a presentation that would mention the significance of both projects but would ultimately highlight the success of the second. When it came time to deliver my talk, I was able to skim over the first project with a quick joke before confidently elaborating on my success with the second."

6. **Be realistic about the time research will take.** Undergraduate research projects often take longer to complete than the mentor expects. This may be particularly true when the student and/or the mentor are first-time REU participants. Consider setting a slightly less ambitious research agenda and budget extra time. Things do go wrong! It is far more satisfying for students to accomplish their research goals than to leave projects half-finished.

Monika Frazier says: "My project was specifically looking at the levels of gene expression among healthy and diseased coral tissue samples. I had collected my samples prior to my arrival and planned on extracting RNA and running it through the arrayer to get some results—a seemingly two-step process. However, first I had to clean and learn how to run a microarrayer that hadn't been used in six years. To make matters worse, the company stopped making microarray machines and could only offer minimal assistance. There were four manuals, which often kept us running in circles searching for protocols and diagrams, which differed among manuals. Needless to say, we spent a lot of time learning about the arrayer! There were also a lot of other things that needed to be prepared for the research to go on. I got my first try at using multi-channel pipettes … and reviewed protocols such as DNA precipitation. In the end—as is the case for many summer internship projects—time was the limiting factor, and we weren't able to get the machine running before I had to return home for school. I'm hoping to return to continue the project when time allows."

7. **Remember that supportive mentoring is crucial.** The single most important factor in a positive research experience is good mentoring. Although different students define "good" in different ways, some general guidelines for mentors would be to try to see things from the student's standpoint. Be respectful of your students and treat them as you would like to be treated. Set appropriate expectations and boundaries. Encourage students to ask questions and share concerns. Assign tasks that are challenging but not overwhelming. Some students are more independent, while others may require more guidance. Ask your students for feedback during the summer and be responsive. Conduct an exit interview and keep in touch!

La'Toya James notes: "Each week, Dr. Repeta and I began by discussing goals, troubleshooting experiments that failed the week before, and briefing each other about events in the community. Meeting with my mentor was essential in providing me with the confidence that my performance was no less than the effort that I had devoted. My mentor also provided feedback and answered my many questions. I learned quickly that the most efficient way to learn was to ask questions of those who were experienced."

Sara Thomas says: "The determining factor in making a good mentor is the ability to place oneself in the mentee's shoes. Whenever I had a question, my mentor was available, even when she really wasn't. She also spent a significant portion of the day with me in the beginning and slowly tapered off as the internship progressed. This was effective because she taught me the skills I would need in the beginning and then challenged me to improve my competence around the lab by allotting me more and more time to work independently."

8. **Consider letting student researchers also become mentors.** If appropriate, give student researchers the opportunity to share their knowledge and develop their mentoring skills by working with younger students.

La'Toya James recalls: "I did not expect to become a mentor during my summer REU, but I was asked to mentor a high-school student who was going to continue the project after the summer. I applied some of the tips and advice that my mentor shared to help the high-school student settle in comfortably. Because she had never worked in a laboratory, she needed assistance in preparing solutions, setting up apparatus, and learning safety techniques. This experience gave me further insight into the qualities that a good mentor should possess and the ways in which a healthy relationship could be established. My mentee was timid and often 'closed-mouth' when she did not understand things. Repeating the experimental procedures a second time seemed to provide a sense of reassurance for her. After the first week, she opened up to me and began to ask questions when she didn't understand procedures or why certain techniques were crucial for the success of the experiment. Asking my mentee for feedback helped me improve my mentoring skills. In particular, I learned that a lack of communication and feedback can be detrimental to a mentoring relationship.

Conclusion

Each of the three students entered the summer REU program with concerns and each experienced at least some problems. Yet all felt that their summer experiences were highly worthwhile. Following are their concluding comments:

Monika Frazier: "I accomplished my key goal of learning a variety of new molecular techniques. I also learned how to persevere and trouble-shoot when things don't necessarily go as planned, which will no doubt be very useful in my research career."

La'Toya James: "Observing the totality of the summer experience, I felt it was a great success. It was the most life-changing research experience of my life. My mentor seemed impressed by the work I had accomplished over the summer and encouraged me to apply to Woods Hole for graduate school."

Sara Thomas: "My feelings about microbial oceanography were transformed from considering it intangible and intimidating to seeing it as comprehensible and exciting. I walked away having learned skills I continue to exercise now that I am pursuing a graduate degree at UH Mānoa."

Acknowledgments

The authors would like to thank the National Science Foundation's Center for Microbial Oceanography for its support and also to thank all the scientists who provided such valuable mentoring to the summer undergraduate researchers. This project was supported by NSF/OIA #0751515 (LJ, ST, MF), NSF/OCE #0751733 (LJ) and NSF/OIA #EF-0424599 (BB).

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