2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #33883

Work in Progress: Evaluation of a Remote Undergraduate Research Experience in Chemical Engineering

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Introduction

In 2019, as part of a large research-focused grant from the National Science Foundation (NSF), a chemical engineering department at a large research university in the mid-Atlantic states created an undergraduate research experience program focusing on computational polymer science. Prior to the COVID-19 pandemic, the intention of the program was to allow students from the university's multiple campuses to gain experience in research, providing them with opportunities that might not be available at their home campus. The original proposal planned for students at the various university campuses to remotely engage in research during the fall and spring semesters, while participate in in-person research at the university's main campus during the summer. The COVID-19 pandemic and the need to work remotely shifted these plans such that the research experience was held in a full remote format during Summer of 2020. The purpose of this proposed paper is to describe the research experience and its evaluation. A case-study approach was used to gather perceptions of three students who engaged in the remote research experience during summer of 2020. Students completed an interview at the end of the summer to describe the benefits and challenges of the research experience, including their perceptions of remote working. Recommendations for other researchers planning to host remote undergraduate research experiences are provided.

Literature Review and Background

Extensive research exists on the potential benefits of research experiences for undergraduates. These benefits include increased research skills (Alexander, Foertsch, & Daffinrud, 1998; Foertsch, Alexander, & Penberthy, 1997; Gates, Teller, Bernat, Delgado, & Della-Piana, 1998; Mabrouk & Peters, 2000), an increased likelihood of attending graduate school (Alexander et al., 1998; Foertsch et al., 1997; Gates et al., 1998; Mabrouk & Peters, 2000; Russell et al., 2005) and increased professional skills such as time-management skills and data analysis (Porter, 2017; Williams, Hussain, Manojkumar, & Thapa, 2016; Zydney et al., 2002).

While research experiences for undergraduates have been in existence for many years, the COVID pandemic in 2020 forced universities to either cancel programs or shift offerings to remote formats. Different approaches to remote labs were attempted in courses, such as Allen and Barker (2021) who used gamified lab simulations in their biomedical engineering course. In addition, researchers were left to figure out how to provide research experiences for their students in a remote setting. Fey, Theus, and Ramirez (2020) provided a case study on how remote research was made available to undergraduate ecology students enrolled in a course. They found that students perceived some benefits to working remotely, including the professional skills gained through working on remote teams. However, while both of these examples provide some indications as to how course-based research can be conducted remotely (providing students with an idea of how research is done), they do not provide guidance on how true undergraduate research experiences, in which students are conducting research in a faculty member's research lab can be conducted.

Batchelor, et al. (2020) discusses how a two-week long research experience for undergraduates at a community college in the geosciences was able to pivot during the COVID-19 pandemic. The students met with faculty mentors who helped them conduct analyses for a narrow research question. Data had already been collected, which allowed the students to work on later stages of the research process.

This study discusses how undergraduate students were able to work remotely during the COVID-19 pandemic on mentored research from a chemical engineering faculty member. The context of the experience is discussed below.

Context of Chemical Engineering Undergraduate Research Experience

The undergraduate research experience was a part of a larger DMREF (Designing Materials to Revolutionize and Engineer our Future) grant from NSF (grant title will be provided in final paper draft). The overall goal of the grant is to accelerate the materials design of organic semiconductors through the combination of experiment and theory efforts.

In addition to the technical research, educational activities proposed for the grant include the following:

1. Use web-based seminar courses and remote mentoring techniques to expose commonwealth campus students to research.
2. Establish a Polymer Materials Design Scholars Program (PolyMDSP) to involve students at the campuses in remote computational work during the year, in addition to summer research at UP.
3. Develop a data-driven Leadership, Management and Teaching (LMT) program that supports students in professional and career development.

The focus of this paper is on the second point listed above, the Polymer Materials Design Scholars Program, which would involve students from the university's many campuses to engage in a remote research experience. The original plan was that the campus students would work remotely on computational work during the academic year, then have a research experience at the university's primary campus during the summer. When COVID forced all work at the university to go remotely, the plan shifted in that students completed their work remotely during the summer rather than at the primary campus.

Students used computational methods to describe the miscibility of polymers in solvents by predicting the Flory-Huggins interaction parameter, and to predict some of the parameters that govern the mechanical response of polymers, such as the friction coefficient and packing length. In most of the work, students leveraged existing methods and approaches developed in the research group they were working on to make progress in their own projects.

Research Questions:

This paper focuses on the experiences of three students who participated in the Summer 2020 remote research experience. Because the plan is to collect data from undergraduate researchers throughout the duration of the grant period, this paper describes our preliminary findings from just one summer; additional data will be collected from students as the grant progresses. In addition

to collecting evaluation data on students' perceived benefits of participating in the research experience, data on the benefits and challenges of the remote format were gathered. Thus, the guiding research questions for this work-in-progress paper follow:

- What benefits and challenges did undergraduates students perceive regarding participation in a remote research experience?
- How can the remote research experience be improved for future undergraduate students?

Methods

Interviews of the three students were conducted at the end of the research experience. The purpose of the interview was to further explore students' perceptions of the research experience. Questions in the interview asked about benefits and challenges of the research experience, benefits and challenges of participating remotely, and suggestions for future experiences.

Participants: Of the three participants, two are female and one is male. Two are chemical engineering majors while one is majoring in materials science. Two were rising sophomores while one was a rising junior. Two of the students planned to get a job in industry after graduating, whereas one wanted to attend graduate school and potentially become a professor.

Data Analysis: All interviews were coded by an advanced doctoral student in educational psychology. The codes and coding process were checked by the lead author on the paper, who is an educational psychologist with significant experience in the evaluation of undergraduate research programs. An inductive approach was used to identify themes relating to the research questions.

Results

Perceived Benefits of Remote Research Experience

Students were asked about both the benefits and challenges of working remotely. Several major themes relating to perceived benefits of remote research are listed below:

- Students felt it was fairly easy to work on computer simulation research tasks remotely,
- Working remotely was perceived to be more efficient since students did not need to spend time getting ready to work,
- Students felt that they had more flexibility in time management and that it was easier for them to tend to other obligations,
- The remote experience required them learn how to work independently, and
- Students enjoyed being able to stay home and yet still be able to do research work.

Overall, students felt that the use of Zoom for meetings made remote working easy. For example, one student said Zoom was easy "because I can just share my screen and show him exactly what I'm doing." Students felt comfortable with Zoom because they had started the research experience in Spring of 2020 remotely. They also had been taking their classes remotely, starting in March of 2020, which also encouraged familiarity with the platform and with remote meetings.

As mentioned above, students felt comfortable being at home, as indicated by the student who said, "It's nice that I get to be in the comfort of my own home…It was convenient that I could be at home and also do research." They also felt like they were able to learn to do their work independently, without much assistance.

Students also felt that the type of work they were doing for the research experience lends itself well to the remote environment. One student said, "My entire [project] was basically based on a program online. I mean, I would have been sitting at a computer in a different place no matter what."

Challenges of remote research experience

While some advantages of the remote research experience are apparent, students did feel there were some disadvantages. Minor things included technical problems (such as one student whose computer broke at the start of the research experience), difficulty scheduling meetings, or a perception that some discussions would be easier face-to-face. The lack of access to a white board during meetings was mentioned by two of the students, who had found this to be helpful during face-to-face meetings in the past. One student said, "Whenever we get more into a theory that he wants to teach me, it's usually a little bit better whenever we're in person. Because when I was at school, I would just go into his office and he has a whiteboard and he has these different models that he can show me. He has some books in there that he can show me. But online, we couldn't do some of that stuff. We didn't have a lot of quick access to something like a whiteboard…So, it was a little bit harder to grasp certain concepts sometimes just saying words and talking." Students also mentioned that access to books and other resources in the office were not readily available in the remote environment. As another issue, students felt that smaller issues or concerns in their work, which were often resolved over e-mail, took longer to communicate than they would have if they had just met face-to-face.

All of the students noted that there are challenges with working from home, including the difficulty with separating the work and the home environment. They mentioned having more distractions at home, such as the student who said, "I'm sitting at my dining room table trying to do this work, and I'm trying to meet with these people, and there's like people doing dishes in the other room. My brother would be playing the electric guitar for the one hour in the week that I need to be meeting with my boss." Other students felt that lack of social interaction with peers and not being around other undergraduates doing similar research work was a disadvantage.

However, overall, despite these challenges, students primarily thought that the remote environment worked well for them.

Description of mentor strategies used in the remote context

Students were asked what mentor strategies were used by the co-PI on the grant. Strategies that were mentioned by students including sharing screens, being encouraging of students, responding quickly to e-mails, and making himself available. One student, who had worked with the co-PI in the past, had noticed that as he got more experienced with the research, the student was provided with greater independence in the work. "I'm getting towards the end of the paper. Starting me on

a new project and so on that one he's not giving me as much help. He's starting to let me do stuff on my own a little bit more." This scaffolded approach is appropriate to use so that students can gain independence in the learning process.

Another student said that the faculty member often looks for opportunities for students to demonstrate or share their knowledge, asking them to explain certain concepts. As one student said, "Whenever he is talking to me about what we're doing, he'll ask me first, like, 'Oh. This is what I see' or he's like, 'What do you see in these results?' and I have to try to explain that. And so being able to look at data or anything and quickly make some type of deduction from that. I think that's a valuable skill that I've gained." Overall, the students were satisfied with the level of mentorship they received in the research experience.

Other strategies that were found to be beneficial were weekly summary meetings and the availability of the PI to receive help as needed.

Suggestions from student interviews

Only two suggestions emerged from the interview data. These included figuring out a way to share information through an online whiteboard and having meetings with other undergraduate and graduate students working in the lab. The latter suggestion was mentioned by two of the three students. The following quotes demonstrate this interest:

- "I guess one thing that probably would be interesting would be being able to see other people's work or something like that and what they're doing or have meetings with people that aren't your professor or a PI. I think that would be something that would help me just keep working because you get to see what other people are doing like, 'Oh, that's really cool', and it can be inspiring and everything, so. I think that would be a good addition."
- "In other situations, I would have had more contact with peers or in this case the people that are also in the same research team – other undergraduates. I've never spoken to [other students] that are doing the same work as me."
- "I think it would be kind of helpful to maybe have contact with other people that are in the group other than just the people that are running it."

Limitations of the study:

One of the limitations of the study is that the research being conducted was simulation based. Faculty who are conducting experimental research may find the remote research experience to be more challenging. One solution to this is to have students work on tasks such as data analysis rather than data collection. Alternatively, an in-person technician, post-doc or graduate student can perform some tasks, with the undergraduate student doing some remote operation for other tasks.

Another limitation is that only three students participated in the research experience during the summer of 2020. However, additional data will be added in future semesters to get a broader perspective on the benefits and challenges of remote undergraduate research experiences.

A third limitation is that this study only describes the experiences of research experiences for students working with a single faculty member. In the future, we may want to obtain data on the experiences of students working with other faculty as well, to again obtain a broader perspective.

One additional limitation is that all of the students had worked previously with the professor on research prior to the COVID pandemic. Therefore, all had worked with him and had developed some sort of professional working relationship. Establishing a relationship with the professor only over remote settings may be more challenging.

Recommendations for others doing remote undergraduate research

Below we provide a list of recommendations for other faculty who are attempting to host undergraduate research projects in remote environments.

1. Check in with students periodically to ensure that they understand their tasks, and that they have the resources they need (e.g., working computer, internet access).
2. Provide a scaffolded approach to lab assignments so that they can continue to grow in their skills.
3. Take advantage of available technology. New software tools and apps are continuously being developed that can help us work remotely. Some apps that can potentially be helpful include online whiteboards, such as those by Google Jamboard, Zoom, or mural). Although all of these tools have limitations, they can potentially simulate a white board experience. The use of a Tablet PC or other writing tool can help to simulate a white board experience.
4. If data collection if not possible, focus on other forms of the research process, rather than data collection. However, provide an overview to students of the entire research process so that they understand all stages, including where the data had come from and how it had been collected.
5. Have group meetings to allow students to interact with others in the research group, including other graduate and undergraduate students.
6. Consider development of students' professional skills. Students may need some guidance to help build strategies that can help the build self-directed learning readiness (Guglielmino, 1991) skills. Share resources with them on how to build these skills. Provide guidance on strategies that can help them with distraction and how to effectively work at home.
7. Emphasize care and empathy in your work with students (Atman, 2020). As novices learning unfamiliar tasks in an environment that currently is stressful, students may feel anxiety. Tell students about your own experiences with working remotely during the pandemic and strategies that worked for you. Consider using reflections with students to help them process their experiences and identify challenges.

As we live and work in the COVID-19 and (eventually) post-COVID-19 eras, we will continue to learn best practices for working remotely, including conducting research with undergraduate students. Our hope is that some of the strategies we have learned will continue to be helpful once

the pandemic is over and normal work can continue. These efforts will help us research more undergraduates and potentially learn professional skills that they can use in their future workplace.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. 1921854: "DMREF: Tuning Liquid Crystallinity in Conjugated Polymers to Simultaneously Enhance Charge Transport and Control Mechanical Properties." Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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