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altREU: An Alternative Online Research Experience Broadens Opportunities for Undergraduates

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altREU: An Alternative Online Research Experience Broadens Opportunities for Undergraduates

Abstract:
Promoting undergraduate students' persistence in Science, Technology, Engineering, and Mathematics (STEM) fields is critical for meeting national calls to strengthen the future STEM workforce. National data has shown that of all students who enter a STEM degree program, less than 40% earn a STEM degree within six years. Calls have been made to produce an additional one million STEM professionals to maintain the countries' relevance in these fields, thus an annual increase in the number of students who graduate with a STEM degree is required to meet this demand. These calls also emphasize the need to increase graduation rates for students belonging to groups that are underrepresented in STEM, as they currently leave STEM majors at higher rates than their represented peers. Undergraduate research experiences are frequently implicated as a means for increasing interest in STEM fields and STEM graduate programs, and are correlated to students persisting to graduation. While research experiences can positively influence persistence in STEM fields, there are inequities in who gets to participate in these experiences. The limited number of undergraduate research opportunities available and the structure of the selection process can contribute to existing inequities.

In Spring 2020, the COVID-19 pandemic forced universities to quickly move to remote instruction. In response, we created the altREU program, a fully online research experience for undergraduate students to continue to provide students with opportunities to conduct meaningful research and develop critical skills during this time.

Here we describe the 'alternative' Research Experience for Undergraduates (altREU) model and report on student experiences in this online research program. In 2020, sixteen students from US institutions participated in the program. The altREU program was designed to attract research-interested students and to broaden participation in undergraduate research. To understand the student's experiences, we collected observations and conducted exit interviews. Twelve of the sixteen students successfully completed the altREU program. Overall, the participants expressed that the online nature of the altREU program did not, to their knowledge, impact their ability to successfully conduct research. Our findings suggest that online research programs may provide a comparable experience to in-person research programs, with the added benefit of potentially reducing barriers that students may face to accessing in-person research opportunities. This paper summarizes the design of the program and gives suggestions for fully online research participation based on program assessment and student feedback. We believe that the altREU model can be relatively easily replicated across institutions.

I. INTRODUCTION

Promoting undergraduate students' persistence in the *Science, Technology, Engineering, and Mathematics* (STEM) fields is critical for meeting national calls to strengthen the future STEM workforce. National data has shown that of all students who enter a STEM degree program, less than 40% earn a STEM degree within six years [1]. Calls have been made to produce an additional one million STEM professionals to maintain the countries' relevance in these fields, thus an annual increase in the number of students who graduate with a STEM degree is required to meet this demand [1]. These calls also emphasize the need to increase graduation rates for students belonging to groups that are underrepresented in STEM, as they currently leave STEM majors at high rates, thus remaining underrepresented in the STEM workforce [1], [2].

Undergraduate research experiences are frequently implicated as a means for increasing interest in STEM fields and STEM graduate programs, and are correlated to students persisting to graduation [3], [4], [5].

Many funding agencies have invested in providing research experiences for undergraduates to support persistence in the STEM fields. The *National Science Foundation's (NSF) Research Experiences for Undergraduates (REU)* program supports undergraduate students' participation in research through funding REU sites (often at universities). In a REU, students typically work closely with faculty and other researchers on a specific research project, and in some cases are granted stipends [6]. Studies have shown that students who participate in REUs show increased interest in pursuing degrees and careers in the STEM fields [3]. REUs provide students with opportunities to develop skills valued by both graduate schools and employers, such as working on challenging problems, presenting research to an audience, and communicating findings through technical writing [3].

While REUs have the potential to positively influence persistence in STEM fields, there are inequities in who gets to participate in these experiences. Questions have been raised as to why some REU programs receive very few applications from students in underrepresented groups [3]. Psychological and logistical factors have been identified that may contribute to this lack of applications. Some of these factors include coming into college underprepared due to lack of access to advanced classes in high school, being intimidated by the application process, being unfamiliar with the program details, and having to work while in school, making it difficult to leave their job for a summer to pursue research [3]. Importantly, students that participate in NSF REUs typically travel to the host university, as these programs aim to involve students from academic institutions where research programs in STEM are limited. In addition to these barriers, the limited number of undergraduate research opportunities available, and the structure of the selection process, can contribute to inequities in who participates in undergraduate research experiences [7].

In this paper, we outline a novel and fully online REU program. We highlight how the online format of this research experience may have reduced barriers to participation, and how the model could be applied to future programs to broaden participation.

The alternative Research Experience for Undergraduates (altREU)

The idea for an ***alternative Research Experience for Undergraduates*** **(altREU)** program evolved from the Spring 2020 COVID pandemic, after being forced to cancel the NSF-funded REU site on "*Computational Modeling Serving the City*" due to the inability to house and have students work on campus during the summer. To better understand the preferences of potential REU participants, an online survey was sent to the 75 applicants. The survey asked if applicants would be interested in a fully online experience outside of the NSF REU program, and if they would consider it without a stipend. In total, only 22 students replied, of those, 13 were interested in an online research experience independent of a stipend, six were interested only if they would get a stipend, and three were unsure. One significant limitation of the altREU program was the inability to provide a stipend to the participants, therefore students that were not able to participate in a research experience without receiving a stipend likely did not respond.

To explore what a fully online research experience could look like, several well-established principles of traditional NSF-funded REU sites were utilized to design a new alternative REU program on "*Computational Modeling Serving Your Community*" that integrated the following foundational pillars: (1) broad, equitable, and international participation, (2) fully online, (3) project-based, (4) student-driven, and (5) community-based.

Previously running two cohorts of a traditional NSF-funded REU site: "*Computational Modeling Serving the City,*" provided the opportunity to rethink potentially problematic program features which had been identified through observation, participant surveys, and a focus group. These considerations include:

1) For students of underserved communities, with disabilities, family obligations, and/or jobs, travel and being away from home for 8-10 weeks during the summer is often not possible.
2) NSF's US citizen restriction, a full-time commitment, and the need to travel to the REU site limit the pool of applicants.
3) Due to the wide variety of project-dependent skills the students are required to learn, the two-week cohort training at the beginning of the REU does not seem to adequately prepare students for their actual projects.
4) Projects proposed by faculty seemed to temper students' engagement and enthusiasm due to a lack of project ownership.
5) The remaining 8 weeks for research following the two-week training period often seemed too short to recover from project setbacks, which left students frustrated, potentially leading to what was identified as lowered interest in continuing research projects and/or in applying to graduate school.

Before launching the altREU program, we hypothesized that a fully online program would be more accessible, allow for broader participation, and a structure that would be in alignment with NSF's REU intentions "*to expand student participation and extend high-quality research environments and mentoring to diverse groups of students"* [8].

II. ALTREU PROGRAM DESIGN

Program Overview and Spirit

A. To address some of the issues we had encountered with our NSF-funded REU site as described in the above, we decided to design the altREU program on the following foundations:

- we accepted applications from all national or international students enrolled in an undergraduate program;
- the entire 8-week program was fully online;
- we aimed to make the program look approachable and less intimidating by using hand-drawn figures and a casual style on the website;
- we only required students to commit to about 4h per day (50% of their time), which allowed them to enroll in classes, work a part-time job, or fulfill other obligations;

- to allow for a non-biased, equitable selection process, we did not collect any demographics or other personal info as part of the application process;
- students would propose and design their own research projects to promote ownership and interest;
- students would learn "on-the-go," i.e., we entirely skipped common training sessions;
- after a week-long "ice-breaker" project to build community, students would directly start with their research projects; we used the time they worked on the initial project to find faculty mentors for them;
- we let students decide whether they wanted to work on teams or individually; and
- we decided not to use surveys to assess the program, instead, we opted to evaluate student progress through observations (proposals, Kanboard, presentations, etc.) and exit interviews (described later).

A Non-conventional Application Process

In an attempt to broaden participation, we deliberately made the application process non-conventional and free of any prerequisites. The assumption was that many students may be intimidated by the traditional REU site application processes, which often requires students to have specific prerequisites, high GPAs, and otherwise be "successful" academically in the traditional sense. The traditional application process, we hypothesize, has the potential to favor students who were already successful, know how to write winning applications, and quite often already have previous research experience.

We designed a non-conventional application process with the following selection criteria in mind: we wanted to attract students who were intrinsically motivated, creative, able to think outside of the box, and able and willing to learn effectively. Through our NSF REU site, we found that neither a traditional resume nor the GPA or a *Statement of Purpose* (SOP) are good predictors for attracting intrinsically motivated and creative students. In fact, students with lower GPAs or with less experience in writing good SOPs may simply be overlooked by selection committees.

Our simple application form asked for the following info: name, e-mail address, GitHub link (if available), LinkedIn profile, the current school, and the current country. In addition, we asked students to create (1) a short video or audio clip and (2) an infographic. The infographic was supposed to tell the story of who they are, where they are in their life right now, and where they are going. The video or audio clip was supposed to provide answers to the following questions: (1) To what extent do you personally care about doing well in this program? (2) Do you think you will enjoy the researched-based nature of this program? (3) Do you think that participating in this program will be useful to you in the future? (4) Do you foresee any challenges to participating in this program? (5) Do you already have a project or problem in mind that would serve your community and that could be solved by computational methods? If so, provide a brief overview of your vision. (6) In the near or far future, mankind may build machines that can perceive, feel and act. How should they be treated compared to animals of comparable intelligence? Should we consider the suffering of "feeling" machines?

While we did not have any required skills for the program, we required students to have access to a computer (not just a tablet or phone) that allowed them to write code, have a decent webcam and microphone, a stable internet connection that would allow for video teleconferences, and a comfortable place where they could work relatively undisturbed. We recognize that these criteria likely were exclusive for some students.

The different software tools (e.g., Slack, Kanboard, Github, wiki) that we required were available for free. If students had to run large(er)-scale numerical simulations, we would provide them access to the *Portland Institute of Computational Science* (PICS) computing resources.

Student Selection

19 domestic students applied to the program. We ranked each application on a scale of 1 to 5 according to the following criteria: creativity, care, enjoyment, usefulness, challenges, project, and infographic. The sum of these criteria formed the final individual score. Based on the final score, we admitted 16 students.

Demographics were collected later, as part of the acceptance form. Of the 16 accepted applicants, nine identified as women, six as men, and one preferred not to answer. Nine were white/non-Hispanic, four Asian, one Native Hawaiian or other Pacific Islander, and two students declared "other."

Program Structure

We ran altREU as an 8-week program to stay in alignment with traditional REU experiences. Figure 1 shows a timeline of the program.

During the first week of the program, we randomly assigned students to teams of 3 or 4 and had them complete a “warm-up” modeling project proposal on how many Christmas trees would need to be planted in 2020 to satisfy the market in 2027. The purpose of this activity was threefold, we aimed to: (1) build community, (2) use the time to find faculty project mentors, and (3) have students complete a detailed project proposal. The proposals included the following components: title, project goal, project timelines, project deliverables, community benefits, resources, risks, and teaming.

Students were given a template for a project proposal and were asked to write up a research plan with a rough timeline, required resources, and other details. Once each student had an individual project proposal posted on the altREU’s internal wiki page, we let them decide whether they wanted to work individually on their project or team up. Four students chose to work individually, six students chose to work in pairs, and four students teamed up to work together as a group.

By the beginning of week two, we had found a qualified faculty mentor for most projects, either at Portland State University or elsewhere, who was comfortable to advise and mentor the student(s) over the summer. The tight timeline made the faculty mentor search process rather challenging, but we ended up with an enthusiastic set of mentors willing to volunteer their time over the summer.

<u>Communication</u>

We mainly relied on Slack for our all-cohort communications. Different channels helped to focus the content and discussion. Students reported that they also used e-mail and text messages to communicate in their teams.

<u>Daily tasks</u>

We asked students to check Slack and e-mail daily, even on days when they didn't work on the project. For each day they did work on the project, we asked them to: (1) check in with their teammates if they worked on a team; (2) update the Kanboard; and (3) update their Github.

Weekly tasks

We asked students and faculty mentors to check in at least once per week. Some students met more frequently with their mentors, but a weekly check-in seemed to work for most. In addition, we held weekly 1h cohort meetings on Zoom. We generally asked for quick 1-2min project updates from all, and then focused on professional development topics that the students had selected through voting on a provided list of options, e.g., how to get a research position, how to pick a grad school program, personal statements and recommendation letters, resumes, NSF GRFP.

Presentations

Students gave a total of 3 presentations: (1) a presentation of the warm-up project, (2) a mid-term presentation in Ignite style (20 slides, auto-advancing in 15s intervals), and (3) a final Prezi presentation. All presentations were recorded and we published extracts on social media. The presentations are also available at https://teuscher-lab.com/altreu/showcase.

Deliverables

To broaden the impact of the projects, we asked students to produce a 20-45min podcast of their project that would be understandable to a layperson. The podcast had to answer the following questions (inspired by the Heilmeier questions [9]): (1) What are/were you trying to do? (2) How is it done today, and what are the limits of current practice? (3) What is new/different/better in your approach? (4) Who cares? If you are/were successful, what difference will it make?

The podcast also had to contain an interview with the faculty advisor and an interview with a community member/stakeholder that would benefit from the project. Podcasts are available at https://teuscher-lab.com/altreu/showcase. Podcasts, presentations, and an extended abstract were also published on PDXScholar at https://pdxscholar.library.pdx.edu/altreu_projects.

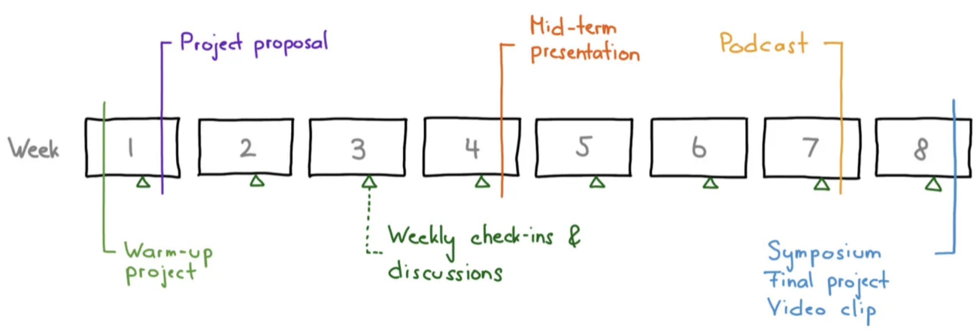

Figure 1. Timeline of the 8-week altREU program.

Program Assessment Design

We opted to assess our program through direct and indirect measures and observations. We relied on Kanban boards, a wiki, and Github to track student's progress. We also conducted exit interviews with the participants (PSU IRB #206955-18).

Program completion

Students were considered to have completed the program if they participated in the final symposium. Twelve of the sixteen initial participants completed the program. Four participants left the program at various points throughout the internship for various reasons.

Kanban project management

Kanban is a lightweight project management process that applies many of the values and principles of the Lean and Agile frameworks. In Kanban, there are no fixed iterations or sprints, just a constant flow where work items are pulled from one stage to the next. This makes it particularly suited for research projects. At the heart of the system is the Kanban board, a physical or digital project management tool designed to help visualize work.

We used the open-source Kanboard project management software (https://kanboard.org) that we installed on one of our servers. Kanboard focuses on simplicity and minimalism and offers basic features only, so that the students were not overwhelmed with a new platform. Figure 2 shows a simple 4-column setup with stacks of cards for the *Backlog*, *Ready*, *Work in progress*, and *Done* categories.

Kanboard allowed us to track the student’s progress in a very detailed way throughout the 8-week internship. For example, Figure 3 shows a cumulative flow diagram that illustrates the project progress of one of our teams. In such a diagram, it is easy to see if students are not making progress, and their faculty advisors can then intervene if necessary.

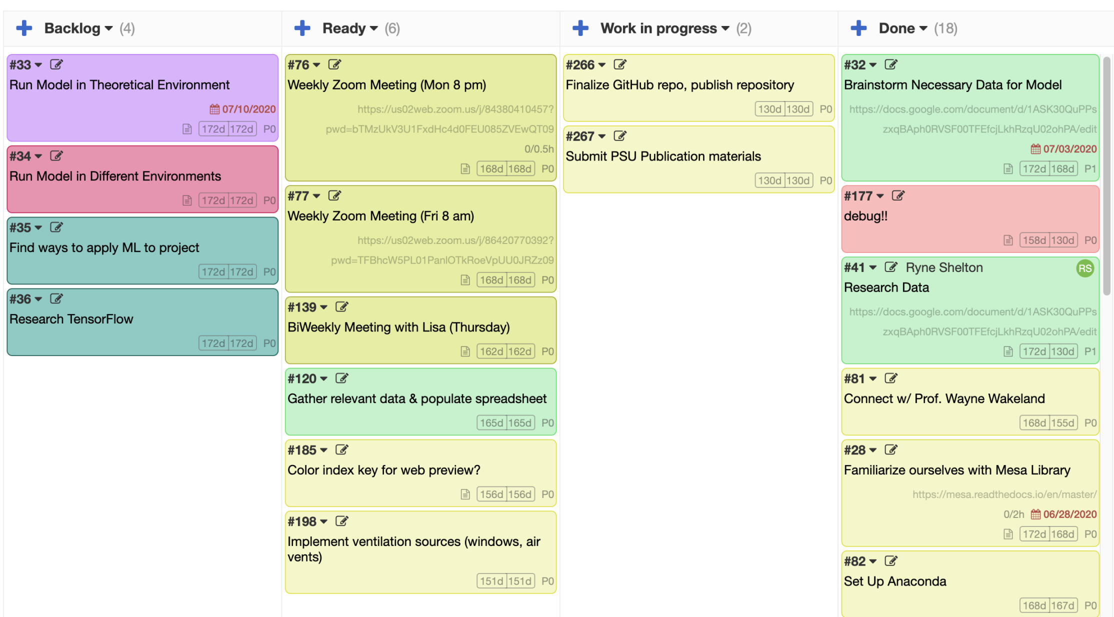

Figure 2. Sample Kanboard setup with stacks of cards for the *Backlog*, *Ready*, *Work in progress*, and *Done* categories.

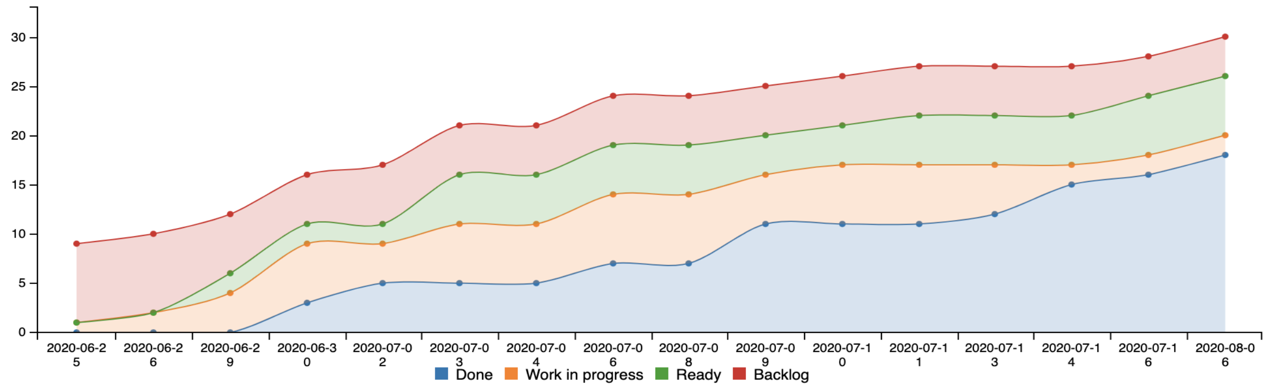

Figure 3. Cumulative flow diagram that illustrates the project progress of one of our teams.

Wiki

As a repository for all cohort-related documents, resources, and instructions, we set up private MediaWiki (https://www.mediawiki.org), a collaboration and documentation platform. Students were able to edit any page and to contribute new content, e.g., pages on how to solve certain problems, use specific software, etc.

Exit interviews

All participants that completed the program were invited via individual emails to participate in an exit interview. Two researchers iteratively developed interview questions with the intention to understand how the remote aspect of the program impacted the participants' research experience. Semi-structured interviews were conducted using a guide composed of a pre-determined set of questions, allowing the interviewer to follow the ordered set of questions while allowing for the natural flow of conversation [10]. Eleven of the twelve students that completed the program participated in the exit interviews. Interviews occurred via Zoom and lasted no longer than 30 minutes. All interviews were audio-recorded and transcribed verbatim. Participants were deidentified, and the text analyzed for salient themes through inductive and deductive coding.

III. Program Assessment Outcomes and Insights

The exit interviews were designed to understand more about the participants' experiences in a remote research environment. Participants discussed various aspects of the program and how the online nature of the program impacted their experiences (Table 1). The participants also discussed what they gained from participating in the program.

In regard to participating in an online research program, students mentioned initial concerns about motivation and logistics:

> *"I was in a group. I was concerned about how that would work when I knew I wanted to be in a group, but I didn't really know how that would work online."*

Many mentioned that they were able to overcome emergent barriers through consistent communication, and that they were able to productively conduct research in an online environment:

> *"I think initially it was very confusing and it felt like 'Oh, I'm just going to be physically home alone doing this.' It just turned out to be much more flexible."*

The participants also discussed what it was like working with other students and their mentors in the remote environment. They stated that this aspect of the program was similar to what they would expect if the program had been in person, and that the remote environment itself didn't result in particular issues.

Whether or not the participant was interested in pursuing graduate education was discussed in the interviews (Figure 4). When asked if they planned on pursuing graduate level education, nine participants indicated yes, one participant indicated that they were unsure, and one participant indicated that they were not interested in pursuing graduate education. When asked if they planned on pursuing future research opportunities, all eleven participants indicated that they would be pursuing more research opportunities in the future (Figure 4). When asked if the altREU program provided an accurate representation of the research process, all seven participants indicated that they felt the altREU program accurately represented research (Figure 4). This question was added during the interview process, resulting in only seven participants responding to this question.

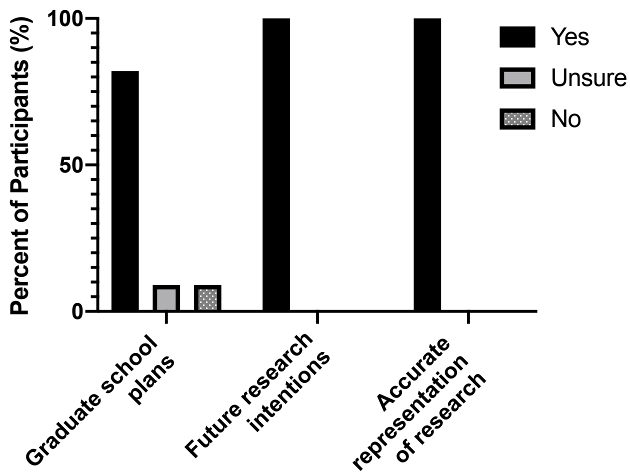

Figure 4: Student Plans. Student responses to the questions: "Are you planning on pursuing graduate school?" (*n*=11). "Do you expect to pursue more research opportunities in the future?" (*n*=11). "Did the altREU program provide an accurate representation of the research process?" (*n*=7).

Table 1: Interview participants' perspectives on program components.

Program component	**Student responses**
Participating in online research	*"I enjoyed it. I think the most difficult part for me was trying to figure out the logistics of making everything work but I enjoyed conducting the research. Sometimes it was hard to stay motivated, but that's the nature of working from home."* *"It was better than I thought it might be. I was a little worried coming in, but the communication was really great. The weekly meetings were valuable and I'm working with my team. The project we were doing didn't need to be in person. We would schedule Zoom meetings when everyone was available and that worked really well."*

Working with other students remotely	*"Not that much different from in person. We still communicated through text, Slack, and we just did Zoom meetings instead of in person meetings."* *"I liked working with another student, because we were using different techniques that were new to both of us, so it was nice to have that support system. Slack and Zoom made it really easy. You come to different conclusions when you're able to talk to each other for a longer period of time and Zoom and Slack obviously limit that but we didn't run into any problems."*
Working with mentors remotely	*"It was good, it was effective. We didn't seem to have any issues with that. Our mentor was very helpful in helping us access other resources. She was not necessarily the one we went to with all of our questions, but she helped direct us around. We did most of our communication through email and Zoom and that seemed to work well for us."* *"It was not as different as you would have expected because I think even if it was in person, you wouldn't be seeing your mentor every day. We'd talk with them over email and then have a few remote meetings. It didn't seem that different than what would have happened in person. I think it was pretty similar."*
Most important skills developed in the program	*"I think being exposed to the whole research process. I've never done it before, it was my first time. That was really helpful."* *"The most important skill would probably be finding ways to delegate the tasks. So we had a lot of things and different facets of what we were trying to focus on. And I think that finding ways to work with the team and effectively split that up. It was difficult at first because we weren't really sure how to do that in the context of doing it all online and making sure everything went smoothly. Once we got into the groove of that it worked really well for us."*
Challenges faced in the program	*"Trying to stay consistent with everything. In person, it probably would have been easier to say, 'Okay, we're here, we're on. We have a consistent schedule. We're working with that.' Whereas from home, it's been tough, especially because this program was so self-driven.* *"Initially I was nervous about being on my own, we were starting from scratch and that's just really intimidating, especially with computational modeling. It's a very vague thing."*
Most positive aspect of the program	*"The weekly meetings, it was definitely nice to see the same people."* *"The teamwork. The team aspect was really useful."*
What could have improved their experience	*"At the beginning when we were picking teams and getting started, the scramble to find people who had similar interests and defining the projects was a bit nerve wracking. Icebreakers and more structured activities to get to know each other would make that easier."* *"More guidance on narrowing your topic in the beginning."*

IV. **Program Continuation**

We offered to provide support for altREU students who wanted to continue their research project. At the end of the 8-week program, 8 of the 12 students that completed the program decided to continue with their research projects. Most of the 8 students continued with the same faculty mentors, a few students looked for other or additional mentors at their schools.

We have continued to hold regular meetings where students present their project progress. Students also took the lead to organize additional career meetings as well as game nights. Several students are working toward a publication.

We attribute the surprisingly high level of student interest in continuing their projects to the project ownership feeling they have shown since the beginning of the research experience, when they proposed and designed their own project. This is consistent with research examining course-based undergraduate research experiences, finding that students who reported greater project ownership also reported greater intentions to continue in the sciences [11]. An additional factor may be that the meeting medium did not need to be changed, i.e., both the students and the faculty mentors were used to meeting on Zoom and could simply continue that practice after the internship.

V. COMPARISON WITH TRADITIONAL NSF REU PROGRAM

Prior to creating the altREU program, we ran the NSF REU program on "*Computational Modeling Serving the City*" for two years. This ten-week program includes two weeks of training and eight weeks of apprentice-based research where students worked with a faculty member to conduct research. The program was conducted in person, requiring students to travel to campus to participate. A regular NSF-mandated stipend was also provided.

As part of the evaluation of this program, a post-internship follow-up survey was sent to participants during Spring 2019 to evaluate their experience (PSU IRB #206991-18). This survey asked participants if they planned on pursuing graduate school, if they were currently conducting research at their university, and if they would have continued to work on their REU project given the opportunity. Nine of the sixteen participants spanning two cohorts participated in the survey.

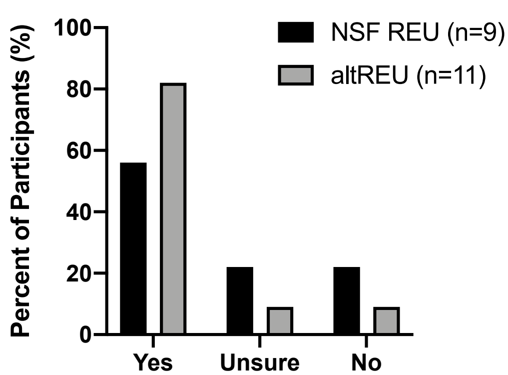

Figure 5: A comparison of altREU participants (n=11) and NSF REU (n=9) participants and their intention to pursue graduate education.

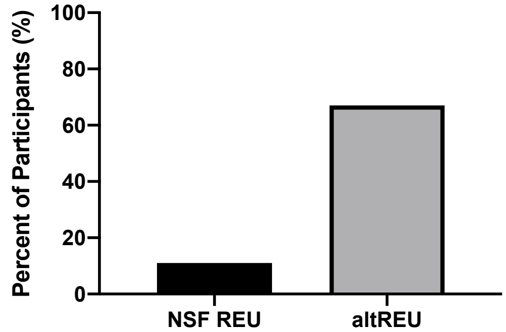

Figure 6: In total,11% of the NSF REU participants (*n*=9) and 67% of the altREU participants (*n*=12) continued to conduct research after participating in the programs.

Out of the 9 responses, five of the NSF REU participants planned on pursuing graduate education at the time of the survey. Of the 11 interview responses from the altREU participants, 9 of the participants planned on pursuing graduate education at the time of the interviews (Figure 5). Two of the 9 NSF REU participants were unsure about pursuing graduate education, while one of the eleven altREU participants were unsure about pursuing graduate education. Two of the nine NSF REU participants don't plan on pursuing graduate education, and this is true for only one of the eleven altREU participants.

Only one of the nine NSF REU participants are currently conducting research at their institution (Figure 6). Of the sixteen initial altREU program participants, eight of them continued conducting their research project (Figure 6).

When the NSF REU participants were asked if they would have continued to work on their REU research project given the opportunity, two said yes, four were unsure, and three said no (Figure 7).

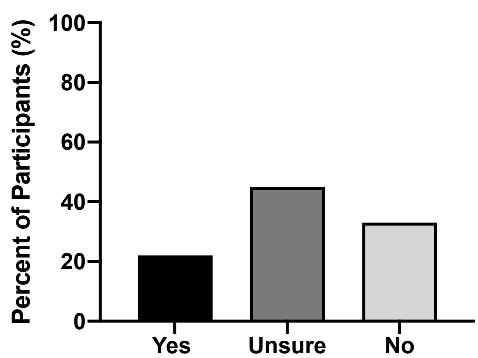

Figure 7: Percentage of NSF REU participants that would have continued their research project, given the opportunity (*n*=9).

VI. Lessons learned

Based on our altREU experience, prior NSF REU experience and program assessment, we present a list of possible considerations for REUs and areas for future research moving forward.

- **Barriers to diverse applicants:** The traditional NSF REU Site application process may be intimidating and give an advantage to students who know how to put together strong applications. The altREU application was designed to be more inclusive through a more simplified, non-conventional process. We observed that the process allowed students to stand out who would not necessarily stand out in a typical application.
- **Time commitments and incentives:** Traditional NSF REU sites are required to treat the experience as a full-time commitment. There is generally little flexibility to take days off, take classes, or pursue other obligations. We have observed that this can be a major obstacle to many students. The altREU program only required students to commit roughly 50% of their time (approximately 20 h per week), to the program. There was a lot of flexibility when students would spend these hours. Future research is needed to explore how rebalancing time commitments and stipends may impact student experiences.
- **Opportunity for project ownership**: Student autonomy in proposing their own projects may have led to ownership and engagement. Surprisingly, students needed little help in fleshing out their projects and in writing formal project proposals, and they made impressive progress on their projects over the duration of the program. The high levels of engagement and progress made on their projects might be related to the levels of project ownership that came from proposing and working on their own research ideas.
- **Reduce formalized training time**. Students were successfully able to learn on their own (and with the help of faculty mentors) the skills they needed to complete their project. Because of the diversity of the projects, it would have been difficult to offer training sessions that would have covered the required skills across all projects. We hypothesize that learning the necessary skills on their own may have led to a better learning experience, although future research will need to be conducted to better understand these outcomes.
- **Student-driven online community building:** Community building can be challenging in online environments, but it is possible that community building might look different in an online research environment compared to a traditional research environment. Students who worked in groups self-organized and quickly built their own communities by using their own preferred communication channels. A good number of students also simply enjoyed working on their own. Students, however, did mention that it would have been nice to hear more from others during our weekly meetings to learn more about each other’s projects. A quick update from each team at the beginning of the weekly meetings might have helped to build community across the entire cohort.

VII. CONCLUSION

We designed and implemented the altREU program: a novel, fully online, project-based, student-driven summer research experience. Here we describe the structure of the program, which aimed to address potential barriers to participation that may be present in traditional research programs, and provide data describing the student’s experiences in the program.

We specifically aimed to remove potential barriers in both the application process and the actual research experience to broaden the participation of diverse students. The fully online aspect of the program may have reduced barriers for students who would not be able to travel to a traditional NSF REU site, e.g., because of family or other obligations, a disability, etc. The non-traditional application process may have allowed students to stand out that may not typically stand out in the traditional NSF REU Site application process.

A large percent of the altREU participants continued their research after the program ended and demonstrated interest in pursuing graduate level education. In our experience, project ownership seemed to influence whether students wanted to continue their research and whether they were interested in graduate school. Project continuation was likely influenced by the fact that physical location did not play a role and that the communication medium with the faculty mentor was already established and did not need to be changed.

Overall, the participants expressed that the online nature of the altREU program did not, to their knowledge, impact their ability to successfully conduct research. Many mentioned that the online communication and format was similar to what they would have expected to experience during an in-person program, and even recognized the advantages of working remotely:

> *"Even if it was in person, you wouldn't be seeing your mentor every day. Talking with them over email and then having Zoom meetings didn't seem that different than what would have happened in person."*

> *"I think it's probably easier to schedule a 30-minute appointment with somebody just randomly online and find a time to meet with them than in person can be. I think it worked out surprisingly well."*

Due to the participants' demonstrated ability to successfully conduct research in an online environment, more work should be done to explore if online REU programs can reduce barriers to participation in undergraduate research. This could result in increased participation by many students that do not have access to traditional undergraduate research opportunities. The potential to broaden participation in high impact STEM practices is in direct alignment with numerous national calls for a more qualified, diverse STEM workforce. We believe that this altREU model can be relatively easily replicated across institutions.

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