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The Development of a Virtual Research Preparation and Professional Development Program

Dr. Tiffany A Mathews, Penn State University

Dr. Tiffany Mathews is the Co-Program Director for Education and Outreach for Penn State's MRSEC: Center for Nanoscale Science. She earned her Ph.D. in Chemistry from Penn State and conducted post-doctoral research at Wake Forest's School of Medicine. In 2007, she joined the faculty at Wayne State University in the Department of Chemistry focusing on using analytical techniques to probe the brain. Since coming back to Penn State in 2013, she has transition on developing programs and efforts that help students succeed both in and outside the classroom. Her focus with the Penn State MRSEC is to develop and offer professional development opportunities to MRSEC grad students and postdocs, while supporting summer programming of PREM students.

Dr. Kirstin Purdy Drew, Pennsylvania State University

Kirstin Purdy Drew is an Associate Teaching Professor in the Department of Physics at Penn State University.

Kristin Ann Dreyer , Center for Nanoscale Science (an NSF funded MRSEC)

Kristin Dreyer is the Program Director for Education & Outreach for the Center for Nanoscale Science, as NSF funded Materials Research Science & Engineering Center (MRSEC). She earned her B.S. in Physics and her B.S. in Secondary Education from Penn State and taught physics and mathematics at the secondary and post-secondary level for many years. While raising a family, Kristin continued to develop and implement informal science education summer programs. At the Penn State MRSEC, Kristin currently manages the strategic development and implementation of the grant's education and outreach portfolio, engaging faculty and student researchers in all programs and initiatives.

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Abstract

In response to Covid-19, the Penn State Physics Department and the *Center for Nanoscale Science*, a National Science Foundation Materials Research Science and Engineering Center (NSF-MRSEC), made a rapid pivot of our Research Experience for Undergraduates (REU) program from an in-person 10-week research experience to a virtual research preparation and professional development program which was designed to prepare science and engineering undergraduate and master's students for entrance into the workforce or their continuation in a graduate program. The overarching goal of this virtual experience was to develop and refine professional skills that are often not explicitly taught in science and engineering classes. The program had three distinct areas: (1) Career Preparation (Professional Development & Career Exploration), which provided students with tools to "build their brand" and exposed them to the wide range of career paths one can pursue with a science or engineering degree; (2) Scientific Research Skills, which comprised academic seminars, a scientific journal club, and hands-on educational workshops; and (3) Community Impact and Involvement, where students developed a scientific outreach product. Here we describe the structure and content of the program, the deliverables created, and lessons learned from this unique summer experience.

Introduction

The advent of the Covid-19 pandemic in the spring of 2020 had an immediate impact on summer 2020 undergraduate experiential learning. Research experiences, internships, and other forms of hands-on experiential learning across the nation were cancelled, creating a hole in students' engagement opportunities. These sorts of experiences are a crucial component of undergraduate training, providing tangible real-life experiences and supporting science career decisions [1]. One option to fill this hole was to transition a traditional face-to-face summer National Science Foundation funded research experience for undergraduates (NSF-REU) program to a fully online, remote research mode. For our program of largely experimental research, a pivot to online research was not practical. Instead, we used the research gap as an opportunity to create a summer professional development program focused on scientific communication skills relevant to STEM research, career development activities, and community involvement (outreach) activities. These skills-training opportunities are often part of summer research programs and have been shown to provide significant learning for the student participants [2]. Creating novel professional development programming was of particular benefit to our NSF-PREM (Partnership in Research and Education in Materials) collaboration as we were able to engage an expanded audience beyond the typical REU student cohort, to include all students affiliated with our partner institutions' grants, versus selecting a handful which typically attend Penn State for the in-person experience. By creating the expanded professional development content introduced below and presenting it virtually, we were able to create a program which is scalable, and easily able to be disseminated to students for their benefit.

Although career preparation and science communication are key elements to a science and engineering undergraduate's professional development, time constraints in the undergraduate core curriculum often impair their inclusion into the curriculum. The two venues in which these elements are most commonly addressed are undergraduate seminar courses and summer experiential learning such as research or internships. Summer research programs have a positive influence on participants learning gains in scientific communication, with particularly high gains for underrepresented groups [2]. Since our summer program typically hosts research and graduate-school oriented undergraduate and master's students from a variety of science and engineering majors, creating an opportunity to develop their professional self and gain career-necessary transferable skills was deemed an important and viable option for a fully remote summer program. Correspondingly, we developed a highly tailorable summer program with the program learning objectives (PLO's) shown in Table 1. Learning objectives 1–4 relate to career and professional development; 5–8 relate to scientific research skills, while 9 and 10 connect to outreach and community building. Many of these learning objectives parallel skills mentioned in the STEM Workforce Knowledge Base and Skillset [3-4], affirming their importance to our summer student population. By focusing on skillsets, the authors were able to tune the disciplinary content and relative emphasis of each of the PLO's depending on the needs of the student cohort. The tailor-ability of the program, however, was also incorporated at the individual participant level. Details of the program content developed for the summer of 2020 are described below, including examples of how choices and options were incorporated into each of the programmatic foci allowing participants to engage in content most relevant to them for their career development and personal interest.

Table 1. Summer Professional Development Program Learning Objectives (PLO's)

Participants will:

1. Develop their professional self and public professional presence.
2. Complete career-development activities to bolster their readiness for post-graduation.
3. Be exposed to a wide variety of career options in STEM.
4. Learn details about graduate school.
5. Broaden their scientific network through multiple means.
6. Demonstrate scientific communication.
7. Acquire and demonstrate scientific knowledge in materials science.
8. Demonstrate competency in scientific ethics.
9. Develop and plan for participation in an outreach/broader impact activity.
10. Develop a sense of belonging in their role as a citizen in the scientific community.

Program Structure and Background

Penn State University has a long-standing summer research program for undergraduates in materials research that has been supported by a series of NSF REU site grants and supplements. Student participants were recruited by and supported through a Materials Research Science and Engineering Center (MRSEC) which itself has been a partner in two NSF-PREM programs since 2015. Each summer, students from both PREM institutions and those who apply directly to the REU from institutions across the country are invited to participate in the MRSEC-REU. The

typical student cohort comprises a diverse range of undergraduate and masters level science and engineering students, all with a stated interest in materials research. The diversity of the participant population is by design, due to both the nature of the NSF-REU solicitation, which recommends focusing recruitment efforts on students from historically underrepresented groups in STEM, and the PREM program, which is designed to increase diversity in materials research disciplines by creating research/education partnerships between minority serving institutions (MSI) and universities which are "leading sources of degrees in materials-related fields" [5]. Traditionally, our PREM partners send a select group of their PREM-funded student scholars to continue their materials science research at Penn State during the 10-week REU summer program. PREM REU student-scholars are in a unique position because a summer REU at Penn State is a continuation of their own research from their home institution, integrated within the larger PREM-MRSEC collaboration. Thus, an intrinsic goal of the in-person PREM REU program is to build their PREM and general science and engineering identity. Importantly, we saw the development of this online summer programing as an opportunity to continue to build the student community and sense of belonging and collaboration between institutions even in the absence of research.

For the summer 2020 virtual program, participants were drawn from the general REU applicant pool as well as our PREM partner institutions. In all, 17 undergraduates and 7 masters students participated from 7 different institutions. Eighty percent of the participants self-identified with at least one underrepresented ethnic minority group. Students' disciplinary backgrounds consisted of Engineering (17%), Materials Science (17%), Chemistry and Biochemistry (38%) and Physics (20 %), Computer Science (N=1) and Biology (N=1). Most students (80%, N=17) had at least some prior research exposure for >1 semester, and about 65% had had some practice with scientific communication outside the classroom. Most were considering graduate school, and all were hoping to pursue discipline-related careers. Taking the diversity of students' personal backgrounds, disciplinary, and career interests into account was an important part of designing the curriculum that would be flexible and beneficial to the largest number of students in the cohort.

Despite the absence of a physical presence, the virtual workshop spanned the same 10-weeks as the originally intended in-person summer REU program. Each week consisted of six contact hours (M/W/F for two hours) over Zoom™. Given students were working from home, in many time zones, workshops were scheduled at noon, Eastern time. Invited participants were paid a nominal stipend and were expected to engage fully in all aspects of the program. Workshop format varied from seminars and lectures to breakout room discussions and interactive web-tutorials. Participants had access to a "course" in Penn State's learning management system (Canvas), through which they accessed the schedule, uploaded assigned deliverables, contributed to discussion boards for off-line topics, and answered surveys to provide programmatic feedback.

Social engagement and climate were also an important part of the program design, as building a sense of community and belonging was a programmatic goal (PLO 10). Zoom can, unfortunately, be a particularly disengaging format for conveying information to a cohort of near strangers. Therefore, several strategies were implemented to help with group cohesion and

comradery/collegiality which are illustrated in Table 2. At the start of the program, students were also encouraged to create and present an informational slide about themselves, which they used to introduce themselves to the rest of the cohort. These peer-to-peer engagements and guidelines helped acclimate participants to the online format of the workshop and were designed to help participants build a working relationship with one another.

Table 2: Cohort Building activities

Establishing Zoom Guidelines	"cameras on" when possible/feasible; use of Chat and Annotation features on Zoom.
Ice breakers and Introductions	5-minute ice breakers weekly.
Social discussion boards	Weekend updates; favorite foods/hobbies/movies, etc.
Journal Club groups	Assigned groups to provide a brief overview of the assigned papers to the weekly research seminar.
Breakout room discussions	Small group discussion or feedback on assignments.

Professional Development and Career Exploration Objectives

The first two PLO's of the summer program included a broad range of activities presented via a combination of traditional speaker/PowerPoint delivery and small/large group share-outs. Participants were engaged in creating and editing materials for themselves as part of establishing their digital professional presence.

As an example activity, the CV/resume peer-editing exercise required participants to either create or revise their existing CV/resume or personal statement, and then bring it to a moderated breakout room discussion for peer review. Peer review was chosen because it provided students with the opportunity to view a variety of writing styles and provide constructive comments, both of which can lead to improvement in students' writing [6-7]. To encourage critical feedback and a collegial environment, breakout room discussions were moderated by program coordinators [8]. Some students were further motivated by the peer-review exercise and took additional time and effort to connect with either the program directors (the authors) or other mentors in their network for additional feedback. After the peer review exercise, we observed that students gained the confidence to solicit feedback from the program directors or mentors in their network. Peer review through breakout rooms also helped to improve group interactions in a virtual format as one student indicated *"intimate opportunities to work together were important, as it gave [students] the opportunity to get to know one another."*

Table 3: Summer Program Activities

Career Preparation		**Scientific Research Skills**	**Community Impact and Involvement**
Professional Development	**Career Exploration**		
LinkedIn™ account creation	Graduate School Admissions Panel	Journal Club presentations	Diversity in Science Discussions
CV/ Resume Tips	Graduate Student Panel	Research Seminars/ Symposium	Presentations on Types of Outreach

CV/ Resume Peer review	Industry Career Panel	Scientific Communication Seminars	Outreach Projects
Email Signature File Creation	Science Communication Career Panel	Scientific Ethics	Outreach Project Presentations
	Informational Interviews	Scientific Workshops	Informal Social Activities

PLO's 3–5 focused on career exploration activities (Table 3). Programmatically, the goal was to introduce participants to the wide range of careers that scientist and engineers can apply their talents to in addition to engaging them in traditional panels focused on graduate education and graduate student life. Career panels were broadened to include careers in scientific writing, editing, museum curation, and science policy experts. Numerous STEM career paths were highlighted outside of academia and industry because evidence suggests that recent Ph.D. students across disciplines are more often seeking careers beyond traditional research-based careers [2,9], and that students in the sciences who are not primarily interested in research-based careers have lower career development and search efficacy [1]. Graduate school panels included both admissions expertise and graduate student presentations and perspectives regarding the application process and life as a graduate student, respectively. Evidence shows that engaging in career exploration helps develop student's disciplinary identity and agency [10,11]. After a series of these career panels, participants were encouraged to reach out to their personal, or newly connected network and request an informational interview. The objective of the informational interview was for students to virtually meet with someone from industry, government, academia (graduate student or faculty member), or an alternative STEM career path that was of interest to the student. Interviews conducted engaged Penn State graduate students, faculty, panelists, and connections from their home institutions' alumni networks. In the final week of the program, students shared their experience with the larger group. Participants reported positive interactions with their interviewee, with many of the interviewees offering to review a resumé, connect them with someone in their company or network or alert them to the potential of a career or internship opportunity.

Scientific and Research Skills Objectives

PLO's 6-8 were achieved via activities that included tips for scientific journal article reading, formal scientific communication, and scientific ethics [12], and then provided opportunities for engaged practice. Student participants led weekly journal club discussions of scientific articles suggested by our weekly seminar speakers to prepare for the information they intended to present. Students prepared their journal article presentation in a group via zoom with an external graduate student discussion leader. Peppered throughout the summer were other computer-based disciplinary workshops designed to expose students to research-relevant skills.

Participants in the summer program were also offered the opportunity to present any in-progress research projects from their home institutions, in conjunction with other research-active summer students who were part of a separate NSF-REU program. Almost half the students offered to share their existing research projects. The result was a virtual research symposium in which 30 students presented research projects and all program participants attended the presentations.

Educational research has shown [1,13] that scientific communication skills typically have strong learning gains over a typical summer REU program, and that gains tend to be similar when practiced in a course-like setting. The above activities were created in an attempt to re-create this learning opportunity under the constrained circumstances.

Community Impact and Involvement Objectives

PLO's 9 and 10 aim to engage summer students in their role as a member of the scientific community, both within and beyond the university research environment. These aims also help to introduce the participants, who were funded by the National Science Foundation, to the mission of NSF's broader impacts goal of going "beyond research," or in this case, beyond the virtual classroom. To that end, we developed an outreach-focused set of activities and workshops that allowed students to learn about, develop material for, and engage with the larger community, all the while practicing the art of communicating their disciplinary expertise to a more general audience (PLO's 5-6).

A common assumption is that outreach experiences in which one engages the general public are simplistic and don't require more formal training [14]. Contrastingly, we took the approach that it is critical for scientists to be thoughtful and intentional throughout the developing and planning process with all the stakeholders. Outreach training focused on the mindfulness awareness project goals, the cultivation of community partnerships, and engagement of a non-technical audience in a science or engineering topic. After several initial informal education workshops, the students were given the opportunity to tailor their outreach projects to align best with their personal interests, given the following broad topics: 1) Deliver a talk to high school students about their undergraduate experience as a science or engineering major, 2) Write a draft proposal for the Materials Research Society: Agents for Sustainable Community Change Grant or a broader impacts statement for an NSF-Graduate Research Fellowship Program (GRFP) application, or 3) Develop a draft of a public comment to a federal agency providing relevant feedback on a proposed rule or regulation that is under consideration by the U.S. government [15]. Although the development for each outreach/broader impact project had a different scope and audience, the common themes among all the projects were: 1) taking initiative to reach out to external sources to gather input, expertise or information and, if the project required, to arrange follow-up implementation of the project in the fall, 2) tailoring scientific language (informal science communication) to the audience that their project was targeting, and 3) reflecting upon their experience.

Students had a month to work on their outreach project individually or in small groups after selecting an option and submitting an initial rationale and plan, which was supported through scheduled program check-in time. During these scheduled times, students working on similar projects (or student teams) shared ideas in Zoom breakout rooms, discussed, planned, and defined tasks to move their project forward. At the end of the summer, individuals and teams presented brief overviews of their project, shared plans for implementation, and submitted a written reflection on its impact on their personal growth.

When we asked the students to articulate the intrinsic benefits of their outreach project via reflection, comments lined up nicely with many of our programmatic learning objectives.

Emphasizing a connection with PLO 5, a student commented that "*Yes, I felt that the outreach activity opened up the doors to collaborating with other students and different clubs at my university in order to educate others and benefit our local community with science."* Students affirmed the benefits of the outreach projects as they related to their science communication development (PLO 6) as well: "*I did find the outreach activity beneficial. I chose the high school video, it allowed me to understand/explain electrochemistry and my own project in more basic terms. Sometimes it is difficult for me to explain what my research is about to non-scientific people, but this activity gave me the opportunity to really think about conveying my project to a more general audience."* and *"yes, the outreach activities were beneficial because I was able to learn how to do a public comment."* As a final example, student feedback affirmed the project's role in PLO 9. One student reflected: "*I enjoyed the outreach project more than I expected to and doing it motivated me to do more in the future. Before this project I would have said I didn't know what science outreach was, but now I realize it's very important and I've been doing it for years!"*

A typical part of our summer program includes several deliberate conversations and activities to engage participants in their role as a citizen of the scientific community (PLO 10). These conversations always highlighted the importance and challenges of diversity, equity, inclusion, and sense-of-belonging in science and engineering fields. Compounding this usual discussion, the summer of 2020 included a nationwide amplification of diversity and equity issues, beginning with the protests and riots sparked by the deaths of many Black individuals while in custody of the police. As these events were evolving in real-time on the national stage, there was also a real-time reckoning within the scientific community to acknowledge the complex role of race, diversity, and inclusion in academic and research environments. Programmatically, we decided it was important to take the time on June 10, 2020 to acknowledge and discuss this topic, in line with the events ShutDownSTEM, Particles for Justice, and Vanguard STEM, which collaboratively called for a shutdown/strike in academia and STEM-related businesses and organizations [16]. This shutdown called for a halt of typical academic work to both allow Black STEM professionals a moment of rest from the turmoil of the summer's national events, and to engage the majority population in a time to reflect and discuss gaps in the inclusivity of science [16]. On that day we held an optional discussion/group chat for our summer participants, many of whom themselves come from underrepresented cultures and ethnic backgrounds in STEM fields. Conversations ranged from a discussion of current events, to sharing of personal experiences of discrimination, to brainstorming how academia/STEM students, researchers, faculty and staff can act in academia to create a more inclusive environment.

Program Impact

In the professional development program presented here, students were given opportunities to increase career-opportunity awareness and preparedness, broaden their professional network, grow their disciplinary knowledge, and practice valuable scientific and professional communication skills. Given that this program was developed out of necessity to replace an in-person research experience, evaluation of the value of the program for its participants was extremely important. Thankfully, it was clear that students were satisfied with their experience. Qualitative data below illustrates the positive impact and value of this program on participant learning and growth.

Quotes from participants related to career and professional development activities (PLO 1-3) included comments such as: "*I have really enjoyed and appreciated the opportunities that this program has given me so far to develop my own knowledge of science and engineering and also to strengthen my professional skills in my field. The career panels have been especially eye opening as to potential non-standard career paths I could follow."* and "[The program] *demonstrated the different opportunities, we have in the Physics field. I didn't know physics could be applied in some jobs. It definitely helped me to clarify my goals and to create a realistic plan for the future."* When students reflected on the numerous activities that were offered, we received feedback such as, "*I really liked the peer review of CV and resume. We really helped each other to create a better resumé and to point out things we did not know they were essential or useful."* Another student commented, "*I like most of these activities! The workshop on x-ray. Crystallography was probably one of my interactive activities because it is a program that I probably would have never found on my own.*"

Students were also surveyed for their impressions of the program. Survey questions (based on [17]) were grouped into the three programmatic areas mentioned above. Figure 1A below summarizes the observation that the majority of the student participants affirmed that most of the activities in all 3 programmatic areas supported their growth and development as a scientist/engineer. We observed that greater than 80% of the students felt they had gained an understanding of what future scientific work is like and they gained confidence in their ability to do well in future academic and scientific activities. As one of the goals of the program was to provide students who were stuck at home the opportunity to be part of a larger science and engineering community, we also asked questions of the students related to their sense of community (PLO 10). For this question we found that greater than 65% of them indicated that they felt like a scientist or part of the scientific community (Figure 1B), however, this number was lower than we'd hoped for, and we received numerous suggestions from our participants on how to improve social engagement online if a future virtual program was necessary.

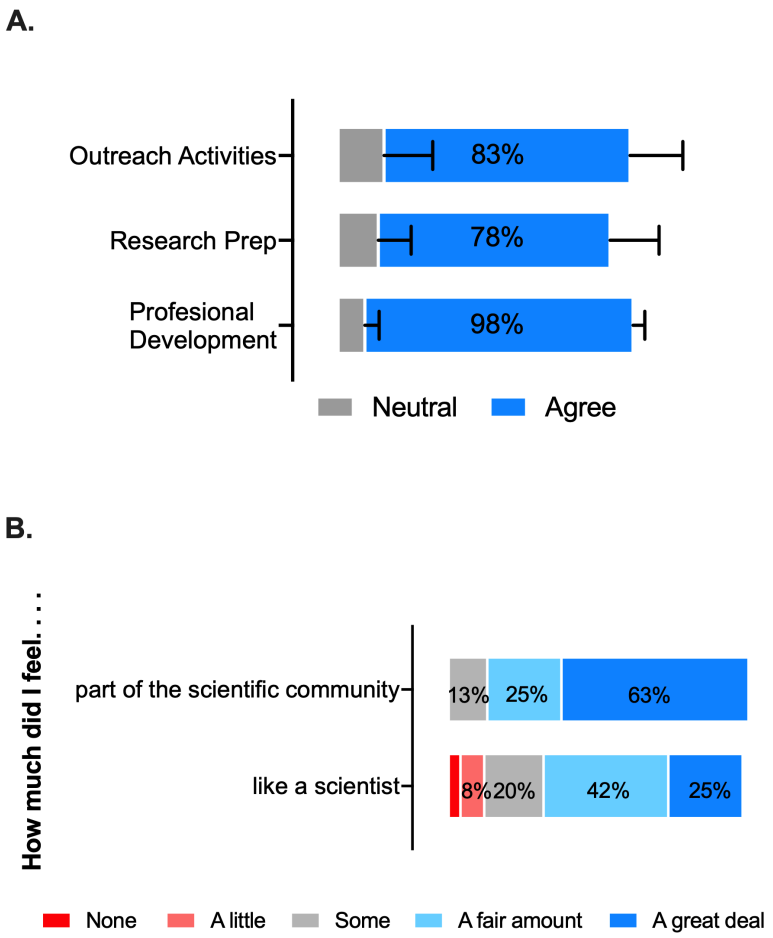

Figure 1. (A) The three programmatic themes in the summer professional development and research preparation program were evaluated. Outreach questions asked the participants how much they agreed with the following statements "The outreach activity improved my understanding of how science and research is conveyed to the public," and "The outreach activity helped improve my confidence and comfort with discussing scientific concepts or science to the public." Approximately 15% of the students felt neutral towards these outreach statements. Research preparation evaluated how the activities supported the students learning, where ~7% disagreed that it supported their learning, and ~14% were neutral. Professional development evaluated how these activities supported the students learning, where < 1% disagreed that it supported their learning, and ~9% were neutral. **(B)** Participants from the summer professional development and research preparation program ranked how much they felt part of the scientific community or like a scientist.

Despite concerted efforts and strategies to address the limitations inherent in an online environment, students were critical regarding the lack of getting to know one another and building cohort community. The ice breakers, discussions, and small break-out room exchanges designed to encourage community and dialogue did not successfully provide enough of the sense of community and engagement the students were seeking. Feedback included suggestions like "*more icebreakers because I couldn't meet everybody."* or *"more activities involving group work*

would be helpful with this experience." Another excellent suggestion from one participant was to *"Have group de-briefs after the weekend... and actually get to know one another. I think that might help us see each other as real people instead of just boxes on a zoom call."* Another student commented *"Linking social media accounts or having group chats with each other."* If virtual programs continue in the greater academic community, the necessity of larger time investment and more effective intentional efforts to create an online cohort and build a cohesive community is a re-occurring theme.

Summary

Despite not having an in-person research component to the summer program, most students felt like they gained useful skills and improved their sense of belonging in the larger scientific community. Taken as a whole, this feedback anecdotally affirmed that the implementation of a tailored professional development-only program was a worthwhile endeavor given the constraints presented in a pandemic.

While this program was developed to fulfill an urgent need, there are lessons that can be learned from the experience and take-away content which can be applied under non-pandemic situations. For example, there are distinct advantages of remote workshops and trainings for students who may have family obligations which prevent them from traveling to an in-person program. Holding remote workshops increases accessibility and equity to those who are otherwise capable but not able to travel. Reversing this paradigm, it is also possible to have guest speakers and workshop presenters from several institutions, when hosting presentations remotely. This turned out to be particularly beneficial to our program, which was developed, in part to continue to foster the collaboration between our university and our partner PREM institutions. In particular, this experience taught us that we can engage with all of the PREM students by incorporating webinars or virtual seminar speakers where physical location of the student is no longer a constraint. Programming can also be expanded to a year-round format. Participants from across the country can be engaged before, during, and after an intensive summer program to provide continued networking, support and mentoring through the academic year. These tactics have been beneficial for the PREM partnerships mentioned in this manuscript with respect to both strengthening the multi-university partnership and student community and sense of belonging. We envision programs like this to also be beneficial within institutions, for example, hosting summer skills development within departments and majors across STEM disciplines.

If you are considering developing a remote workshop for undergraduate professional development, we recommend this combination of disciplinary skills, career preparation, and community belonging and engagement. These three foci are advantageous because the content and organizational details can be tailored as needed to suit the desired learning goals of your student participants, and they touch on all aspects of student professional development. Furthermore, providing flexibility for participants to tailor different aspects of the programming to their interests acknowledges that career exploration and preparation is very personal journey, in the development of in intensive online professional development program, we reiterate the

importance of an enhanced effort towards cohort and community building as recommended by our participants. From a program that was designed to counteract the crisis that Covid-19 pandemic brought to summer research programs, the design opened the doors to expand the REU experience into the virtual realm. Advantages discovered and mentioned above are making the program more inclusive, allowing for the potential to reach and prepare more students, and have encouraged future development of similar programs beyond a 10-week period for students.

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