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Commentary

Virtual Undergraduate Research Experiences: More Than a Pandemic Stopgap

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During the SARS-CoV-2 pandemic, experimental research groups face a unique challenge: how to train undergraduates without access to labs. We share our experience developing entirely virtual undergraduate research internships and make a case for virtual research as a complement to traditional undergraduate mentoring, even after the resolution of the pandemic.

Undergraduate research is a critical component of scientific training, and the summer term affords trainees an unparalleled opportunity to receive mentorship and to be immersed in the day-to-day life of an academic lab, whether at their home institution or in a new environment.[1] Numerous studies suggest undergraduate research experiences are especially important for women and underrepresented minority (URM) students, serving as a bridge to future opportunities in science, technology, engineering, and math (STEM).[2,3] This summer, due to the SARS-CoV-2 pandemic, our primarily experimental lab was faced with a daunting challenge: how to honor our commitment to train undergraduates without access to our physical lab and with only virtual access to our students. Here we share our experience developing virtual undergraduate research opportunities and highlight the unmet needs that may be addressed by virtual research, even after the resolution of the pandemic.

Typically, our summer students spend 3–4 months immersed in our research lab, working and learning full time as a member of our integrated team under the direct supervision of a senior postdoctoral fellow or graduate student. These experiences are sometimes completed as a form of credit-earning coursework, as fellowship-funded positions, or as volunteer experiences. Our goal was to design a virtual program for trainees that would fulfill the same core objectives as a traditional in-person summer experience, despite needing to rely on different tools. We hypothesized that while the conditions we faced in the summer of 2020 prevented us from implementing a precise phenocopy of our preferred face-to-face internships, perhaps we could adapt to our existing constraints to fulfill many of the same outcomes. In engineering terms, we sought to achieve something akin to "biomimicry" in our pandemic-adjusted experiences.

The first priority we tackled was to provide scientific training that was as rigorous as an in-person experience. Li et al. recently outlined in *Cell* the key objectives for an undergraduate training program: "developing technical skills, gaining a broad understanding of the field, learning research rationale and key methodology, designing and managing projects, and improving effective scientific communication."[4] With our lab shuttered, hands-on experimental instruction was not possible, yet we determined that the remaining objectives could be adapted for a virtual setting. Guided by experienced mentors over video chat, our summer trainees learned how to read and critically assess scientific literature—a skill set that is increasingly relevant with the trend toward the online publication of non-peer reviewed, pre-print manuscripts. From their reading, trainees gained the perspective to identify unmet needs and knowledge gaps in their assigned fields and used this perspective to participate in the development of new projects in the lab. Trainees also learned digital tools, and when to use them, in order to analyze data generated from previous wet-lab experiments or to conduct computational projects that complemented their mentors' experimental work. To develop scientific communication skills, students were guided to create and share summary presentations of their summer experience in a virtual symposium, in addition to the ongoing scientific discussions that were held throughout the summer.

Our second priority was to recreate the sense of community inclusion that normally comes with an in-person internship. Immersion in the day-to-day of experimental science offers numerous benefits, including allowing students to gather personal insight into future career choices, gained in part by working side-by-side with senior lab members who form a network of experienced mentors.

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Meanwhile, connections between junior lab mates create a community of near peers with whom they can navigate their next steps beyond a summer experience. Critically, both of these forms of social connection are central to developing a sense of belonging in academic science, a factor that is especially important for the retention and future success of female and URM students in STEM.[5] To help our students to feel immersed, even in a purely remote lab experience, trainees were included in all manner of virtual meetings: weekly group meetings, journal clubs, seminars, brainstorms, casual discussions with collaborators, formal multi-institution grant review meetings, and even "digital happy hour" social gatherings. Mentors made a point to introduce their trainees at the beginning of each meeting and encouraged them to contribute as welcome participants, thus emphasizing our perception that they were active community members and not merely silent observers. We also organized a live video seminar series in which pairs of graduate students and postdocs shared not just their research, but also their professional journey as scientists and their interests outside of academic research, such as entrepreneurship and science policy. This intimate panel-style discussion series gave trainees the opportunity to engage with almost every lab member and to explore the variety of ongoing research initiatives within our group. Moreover, and perhaps most importantly, trainees gained insight into the diverse and non-linear career paths that are possible in biomedical sciences and were in a position to ask candid questions.

Although we were able to adapt many aspects of undergraduate research to a remote experience, replacing in-person benchwork presented unique challenges. The realities of working during a pandemic increased the time demands and schedule constraints related to dependent care for many graduate students and postdocs. This reduction in available bandwidth made engaged mentorship more challenging than usual. We approached this issue by adjusting our conventional 1:1 mentoring paradigm to incorporate a mentorship team, such that multiple lab members were assigned to each undergrad. This strategy helped balance the time commitment across mentors, while also providing the mentees with access to a more varied and diverse set of advisors. Even with this shared load, the sudden shift to virtual mentorship, combined with the absence of resources to guide us in this abrupt transition, resulted in some mentors finding virtual mentorship to be significantly more time consuming; mentors had very little time to develop new, creative ways to design a virtual research experience to be as engaging as possible. However, with our experience of 2020 now in hand, and with the shared knowledge of the wider research community, we anticipate that by establishing guidelines and resources for virtual mentorship, future digital internship experiences will not be inherently more time consuming than traditional mentoring.

One of the most significant challenges presented by virtual research was that while the pandemic enabled us to focus on the important and oft-neglected aspects of scientific training discussed above, without access to a lab our students were unable to develop hands-on experimental skills. We believe that the creative use of technology (e.g., shadowing via live video, remotely driving lab software/instruments, and virtual reality tools) could partially address this shortcoming. Furthermore, while development of physical experimental skills is certainly important for undergraduates, one could argue that with the exception of highly technical, specialized skills (e.g., mouse surgery, cryo-electron microscopy), the intellectual aspects of research, which we found adapt well to a virtual setting, are the components of an internship that most require guidance by a skilled mentor and are those that best prepare an undergraduate trainee for scientific independence. Thus, we found that even in life science and engineering disciplines such as ours, it is possible to provide meaningful learning experiences in the absence of in-person access to physical bench work.

Nonetheless, by far one of the greatest challenges we faced was to recreate the emotional elements that are an integral aspect of an experimental research experience. The excitement that comes with the hands-on work of developing a new technology that will impact human health or the satisfaction that arises upon mastering a new experimental protocol are just two examples of emotions that draw many trainees to bench research careers. No less central to a summer research experience is the frustration of repeated failure—a reality of experimental research—and a lesson that teaches essential troubleshooting and resilience skills that serve any mentee well in their future. As the stay-at-home order was lifted in Cambridge, Massachusetts, during the summer months of 2020, our full-time team members transitioned back into the lab with limited hours, but summer trainees remained unofficial and were never permitted on campus. With these limitations in place, one mentor attempted to recreate the emotional journey of hands-on bench work for her virtual trainee by flipping the traditional mentor-mentee relationship. Namely, instead of the undergrad performing physical experiments for the postdoc, the mentor offered to run experiments at the instruction of the remote trainee. For any assay the mentor ran in the lab, the trainee was invited to generate a hypothesis that could be answered with the addition of one or two samples to the assay. With minimal extra effort for the mentor, the trainee was offered a sense of ownership over the data and some emotional investment in the outcome. This strategy also reinforced our commitment to the inclusion of junior trainees in the intellectual components of projects, rather than just the technical side.

As we reflect on our experience, we find that while the transition to a virtual setting seemed daunting, we are pleasantly surprised at how successfully remote research recreated the core goals of a summer internship. Our trainees certainly received rigorous training and, in fact, without the capacity to mentor at the bench, we rediscovered our commitment to allocate time and attention to the essential, intellectual aspects of undergraduate training. This "bigger picture" focus has always been a desired priority, but it is easily overshadowed by the in-the-moment demands of hands-on, experimental training. Similarly, while the social components of an undergraduate research experience initially seemed impossible to recreate in a virtual setting, by applying our strategy to include trainees in nearly every aspect of the lab via digital engagement and by intentionally fostering connections between trainees and other lab members, we provided the core social benefits and the mentoring network that we strive to establish during a traditional summer immersion.

Informed by our experience this summer, we are enthusiastic about the potential for virtual research experiences to serve as a complement to traditional forms of mentorship, even after the pandemic resolves and undergraduates return to the lab. Maintaining a commitment to virtual research would enable longitudinal mentorship of summer undergraduates after they return to their home institutions at summer's end. As academia confronts its lack of diversity, virtual experiences could be leveraged to address existing inequity in training opportunities that have been observed to contribute to low diversity. Virtual experiences would circumvent several common barriers to access encountered by underrepresented groups, such as work commitments, financial barriers, geographic constraints, and childcare or family commitments,[6,7] and could even be used to engage with such students at distant institutions during the fall and spring terms. Our experience encourages us that virtual engagement could be used as tool to establish meaningful mentorship networks and to foster feelings of belonging, supporting the persistence of underrepresented students within STEM. Indeed, virtual engagement has recently been shown to be an effective platform for a similar purpose for URM STEM female faculty.[8]

Thinking pragmatically, we do recognize that despite our successes in 2020 with a small group of digital mentees, any wider implementation of similar programs would have to be designed thoughtfully in order to avoid propagating existing inequality of access.[9] Existing disparities in access to the internet and digital technology, which are significant even in the US,[10] would mean that virtual research will still be out of reach for some students; to make these opportunities truly equitable, labs may need to consider additional steps to remedy technology access disparities, such as loaning trainees a lab laptop and wifi hotspot. Supporting virtual mentorship as a complement (rather than replacement) for traditional mentorship will likely require the recruitment of additional mentors in order to maintain high quality mentorship for all trainees without overburdening individual mentors. Furthermore, institutional support and recognition of virtual research programs as a legitimate tool for training junior scientists will be essential for the success of such programs. Likewise, given that summer experiences are typically a prerequisite for entrance into graduate programs and job placements, wider adoption of digital mentorships will also require a shift in hiring criteria to value curiosity, commitment to learning, and a growth mindset over publication count or mastery of specific experimental techniques. Hiring managers and senior investigators must embrace the belief that physical techniques can be taught "on demand;" intellectual assets such as the capacity to think critically, plan creatively, and work resiliently on a problem at hand are the more essential skills that identify a trainee as having the foundations for scientific independence and success. We have adopted this general philosophy in our own hiring practices and have seen the advantages it brings.

Looking forward, we are optimistic that the creative use of technology and the adaptation of best practices for undergraduate research[11] to the virtual setting will enable remote research experiences to transition from serving as a pandemic stopgap to a powerful, complementary training tool for a new generation of junior scientists.

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DECLARATION OF INTERESTS

S.N.B. holds equity in Glympse Bio, Satellite Bio, and Impilo Therapeutics; is a director at Vertex; consults for Cristal, Maverick, and Moderna; and receives sponsored research funding from Johnson & Johnson. T.S. and H.E.F. have no conflicts to declare.

1. Seymour, E., Hunter, A.-B., Laursen, S.L., and DeAntoni, T. (2004). Establishing the Benefits of Research Experiences for Undergraduates in the Sciences: First Findings from a Three-Year Study. Sci. Educ. *88*, 493–534.

2. Hernandez, P.R., Woodcock, A., Estrada, M., and Schultz, P.W. (2018). Undergraduate Research Experiences Broaden Diversity in the Scientific Workforce. Bioscience *68*, 204–211.

3. Pender, M., Marcotte, D.E., Sto Domingo, M.R., and Maton, K.I. (2010). The STEM Pipeline: The Role of Summer Research Experience in Minority Students' Ph.D. Aspirations. Educ. Policy Anal. Arch. *18*, 1–36.

4. Li, J., and Luo, L. (2020). Nurturing Undergraduate Researchers in Biomedical Sciences. Cell *182*, 1–4.

5. Fisher, A.J., Mendoza-Denton, R., Patt, C., Young, I., Eppig, A., Garrell, R.L., Rees, D.C., Nelson, T.W., and Richards, M.A. (2019). Structure and belonging: Pathways to success for underrepresented minority and women PhD students in STEM fields. PLoS ONE *14*, e0209279.

6. Bangera, G., and Brownell, S.E. (2014). Course-based undergraduate research experiences can make scientific research more inclusive. CBE Life Sci. Educ. *13*, 602–606.

7. Pierszalowski, S., Vue, R., and Bouwma-Gearhart, J. (2018). Overcoming Barriers in Access to High Quality Education After Matriculation: Promoting Strategies and Tactics for Engagement of Underrepresented Groups in Undergraduate Research via Institutional Diversity Action Plans. J. STEM Ed. *19*, 48–55.

8. Petersen, S., Pearson, B.Z., and Moriarty, M.A. (2020). Amplifying Voices: Investigating a Cross-Institutional, Mutual Mentoring Program for URM Women in STEM. Innovative High. Ed. *45*, 317–332.

9. 2019 NACE Student Survey Report, https://www.naceweb.org/store/2019/2019-nace-student-survey-report-four-year-schools/.

10. Collis, V., and Vegas, E. (2020). Access to Online Learning in the US, https://www.brookings.edu/blog/education-plus-development/2020/06/22/unequally-disconnected-access-to-online-learning-in-the-us/.

11. N. Hensel, ed. (2012). Characteristics of Excellence in Undergraduate Research (Washington, D.C: Council on Undergraduate Research).