

Adapting Undergraduate Research to Remote Work to Increase Engagement

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Demand for undergraduate research experiences typically outstrips the available laboratory positions, which could have been exacerbated during the remote work conditions imposed by the SARS-CoV-2/COVID-19 pandemic. This report presents a collection of examples of how undergraduates have been engaged in research under pandemic work restrictions. Examples include a range of projects related to fluid dynamics, cancer biology, nanomedicine, circadian clocks, metabolic disease, catalysis, and environmental remediation. Adaptations were made that included partnerships between remote and in-person research students and students taking on more data analysis and literature surveys, as well as data mining, computational, and informatics projects. In many cases, these projects engaged students who otherwise would have worked in traditional bench research, as some previously had. Several examples of beneficial experiences are reported, such as the additional time spent studying the literature, which gave students a heightened sense of project ownership, and more opportunities to integrate feedback into writing and research. Additionally, the more intentional and regular communication necessitated by remote work proved beneficial for all team members. Finally, online seminars and conferences have made participation possible for many more students, especially those at predominantly undergraduate institutions. Participants aim to adopt these beneficial practices in our research groups even after pandemic restrictions end.

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Undergraduate research: the transition to pandemic conditions

Participating in undergraduate research provides many benefits to students, including increased science knowledge, confidence, and persistence in science (1–3). These benefits are especially important for students from groups traditionally underrepresented in science, technology, engineering, and math (STEM) (4, 5). However, the positive effects of undergraduate research can be dampened by a mismatch between the desires both on the part of students to participate in research and faculty to provide such opportunities on the one hand and the lack of available capacity in faculty research laboratories to meet student demand on the other hand.

These challenges were expected to be exacerbated by the SARS-CoV-2 pandemic, which in many areas resulted in campuses being closed or at least the density of personnel in research laboratories being dramatically reduced to prevent virus spread. In spring 2020, student dormitories across the United States were evacuated, and only essential workers continued to work in person, with all others transitioning to remote work. By mid-summer, in some areas workers began to repopulate research laboratories, but usually at mandated reduced densities. At some institutions, undergraduates were not allowed to return to laboratory research. This situation presented substantial challenges to integrating undergraduates into research laboratories, both because of the density limits and because of the general need for closer supervision and more hands-on training of undergraduate researchers.

Several recent publications highlight creative solutions to teaching laboratories, including course-based undergraduate research experiences (CUREs), during pandemic-related remote teaching (6, 7). Solutions implemented in project labs and CUREs included pivoting to data and statistical analysis, modeling and simulations, experimental design and troubleshooting, and literature searching (8–14). Although there is no virtual substitute for learning hands-on laboratory skills, research skills and practices can be taught without access to “wet” laboratories. In some ways, undergraduate research with its typical focus on individual student projects and more individualized student-mentor and student cohort interactions posed more of a challenge during the COVID responses (15); for example, whereas many students were completing required courses and thus had to be provided with alternative experiences, undergraduate research can often be considered optional. The individual or small group organization of undergraduate research projects also poses challenges with scaling to increase participation. These challenges are generally true of undergraduate research, which has led to the adoption of CUREs to address this need (16, 17). The pandemic has created additional challenges as faculty were often overwhelmed putting their courses online or with their own children involved in at-home schooling.

Some types of research are more easily adapted to remote work, including some types of disciplinary-based education research and computational or informatics research. Others have converted wet research laboratory experiences to virtual experiences by having students carry out data analysis and literature searching, at first because of lockdowns, and subsequently to maintain low in-person density while engaging undergraduates in authentic research (18).

In general, there is an unmet demand for undergraduate research opportunities in STEM fields. Moreover, various programs may require some research experience or may be structured to encourage research strongly. For example, Northeastern University (Boston, USA) students engage in cooperative (co-op) learning experiences as early as spring of their second year, and many of these students pursue research opportunities to help prepare them for co-op. Additionally, chemistry majors at Northeastern University are required to complete at least one semester of undergraduate research. Over the spring and summer of 2020, many formal and informal discussions were held across colleges and universities, facilitated by professional societies and funding agencies, to prepare faculty for the fall semester, including discussion of engaging undergraduate students in research (15, 19, 20). This perspective provides examples of

how research groups continued to engage undergraduates in research despite lockdowns and reduced laboratory density. We discuss overcoming challenges of engaging students in research, as well as benefits that have resulted from the current restrictions.

Benefits of the online environment

One positive aspect of the COVID-19 pandemic has been increased interaction and integration of undergraduates at predominantly undergraduate institutions (PUIs) with scientists at research-intensive institutions. Many new opportunities have emerged, from watching large, somewhat impersonal online webinars with prominent researchers (21), to participating actively in cross-institutional virtual research group meetings, to even attending international conferences online.

Although useful for all students, virtual meetings are of particular benefit at PUIs to expose students to research careers because these undergraduates do not have the opportunity to observe graduate students and postdoctoral researchers carrying out full-time, intensive research. This open access to high-quality research is expected to help remove barriers to the participation of diverse groups in science, especially at institutions with many historically underrepresented minorities and first-generation college students who may be less knowledgeable about scientific career paths. After the normalization of virtual meetings during the pandemic, we anticipate continuing benefits to undergraduates by connecting them to other scientists who can serve as examples. Future goals of one faculty member (LSW) include having students interact with authors of papers in a research group journal club or class session, engaging in informational interviewing with graduate students and postdoctoral scholars, and collaborating with undergraduates at other institutions.

At research universities, undergraduates often carry out research under the direct supervision of graduate students or other senior members of the group. One benefit of online group meetings is the ease of including more members of the research team in project meetings, regardless of location, so that all members of the team can engage in discussions and benefit from the expertise of the group members. The Northeastern University Department of Chemistry and Chemical Biology has long had an Industry PhD program in which students work toward a PhD while maintaining their full-time employment elsewhere. Thus, many group meetings and seminars already included online broadcasting; this has now become better institutionalized, making these meetings more accessible to others, including students off campus on co-op.

Research projects

A number of adaptations of research projects and activities were introduced to continue to engage undergraduates in research. In some cases, laboratory density allowed occasional or rotating in-person work, and in others only remote work was possible. Several examples are briefly highlighted here; detailed descriptions of projects can be found in the Supplemental Material.

In several examples, in-person and remote students collaborated through online notebooks and file sharing sites to organize data and facilitate communication. Students in the CaNCURE co-op program (22) were able to publish manuscripts from their time in lockdown (23, 24). Data analysis, modeling and simulations (25), and data mining projects (26–29) were pursued with a range of applications. Students also gained more experience in reading the literature (30) and wrote review articles. Bioinformatics and genome mining (31–33), homology modeling, modeling protein-protein interactions (34–38), molecular dynamics simulations, and electrostatics calculations (39–41) were carried out by undergraduates working remotely. These projects were carried out in many cases by students with little or no formal training in computational methods, and yet in many cases, students were able to make substantial progress in only one semester.

Conclusions

This work highlights the challenges that the SARS-CoV-2/COVID-19 pandemic imposed on undergraduate research and how researchers were able to adapt projects to engage students for remote work. Although there are numerous challenges associated with conducting research during the pandemic, there are benefits as well. These projects in some cases moved research in new directions. The opportunity to meet regularly away from the laboratory gave the chance to have all students involved in data interpretation, close reading of literature, and aspects of manuscript writing in small teams. In other cases, more in-depth discussions among research teams led to deeper learning, greater student ownership of projects, and a more dynamic research environment. Several researchers noted that remote research allowed closer interactions between undergraduates and PIs than might normally be the case. These arrangements also helped students to develop a research mindset before entering a wet laboratory. It will be valuable to incorporate these practices more deliberately in the future. Thus, there are numerous benefits to undergraduate students, faculty, and research groups to engaging undergraduates in research in this new environment.

SUPPLEMENTAL MATERIAL

Supplemental research project descriptions are available at: <https://doi.org/10.35459/tbp.2021.000199.s1>.

ACKNOWLEDGMENTS

This work was supported by National Science Foundation (NSF) CAREER Award MCB-1845953 (to SEC), Northeastern ADVANCE Office Mutual Mentoring Advancement Program (to A-ADJ), NSF CHE-1905214 (to MJO), NSF CHE-2030180 (to MJO), NSF-DBI-2031778 (to MJO), National Institutes of Health (NIH) 2 R25 CA174650-06 (to SS), Research Corporation for Scientific Advancement grant 23595 (to LSW), NIH 1R15GM137249-01 (to LSW), NSF MCB-1615946 (to PJB), NIH R01GM123239 (to PJB), and Research Corporation for Science Advancement LEAD award 25663 (to PJB). The sponsors played no role in the preparation, review, or approval of the manuscript. We also thank the students who rose to the challenge to keep research moving forward.

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