The Biophysicist

Perspectives on How 1.5 Years of the COVID-19 Pandemic Have Impacted Biophysicists at Primarily Undergraduate Institutions

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The COVID-19 pandemic impacted the biophysics community at all levels, including effects on every aspect of teaching and research at primarily undergraduate institutions (PUIs). The US National Science Foundation defines PUIs as accredited colleges and universities that award fewer than a particular threshold number of PhD degrees per year (1); a more global definition might include institutions that have little to no doctoral student presence and a central mission of teaching and training undergraduates. Biophysics faculty at PUIs are often hosted in biology, chemistry, or physics departments and teach introductory and upper-level courses, often without graduate teaching assistants. We lead research labs with varying levels of funding and access to instrumentation, focused on training undergraduates through their own directly mentored scientific projects. Because faculty at PUIs have different needs than at research-intensive institutions, the Biophysical Society has recently launched a PUI Network for current and aspiring PUI faculty to share their experiences (2). Much of the PUI Network's initial work has been COVID-19 related, as the transition to pandemic life and work during this time of restrictions and uncertainties required extensive faculty engagement and self-initiative in the classroom and our research labs. Here, we share highlights from narratives of our individual experiences and summarize lessons learned that may be helpful for other PUI faculty and the broader biophysics community.

There is a growing body of literature and resources on the impact of the coronavirus pandemic and what approaches to teaching might be

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useful in the current and future crises (3–7). While the effect of the pandemic in higher education has been described at the level of research-intensive institutions and single departments (8, 9), its impact on the biophysics educator community at PUIs was thus far only scarcely covered. Therefore, to add value to the current body of literature, we have collected personal narratives from biophysicists across a range of PUIs with different institutional characteristics and learner populations. The reflections presented here enrich and complement the more general biophysics education literature by providing individual observations about our personal experiences performing undergraduate-level teaching and research during the pandemic. Each of us has creatively adapted our practices in the (virtual) classroom and lab to continue providing undergraduate teaching and research mentorship both during the transition to pandemic life and throughout the period of COVID-19 restrictions. Our narratives consider the impact of childcare responsibilities, the various demands of teaching introductory and upper-division courses (lecture-based vs. lab-based courses vs. seminar courses), teaching support (limited or no teaching assistants), consistency with pre-pandemic pedagogical approaches, and faculty and student access to digital technology resources.

We realize that what might work for one instructor is not always obviously applicable to another due to the unique nature of each institution, its student population, and the differing expectations for undergraduate teaching, research, and mentoring that exists even among PUIs. For this reason, we summarize narratives from faculty across a diverse array of undergraduate-serving institutions and departments. In addition, we have established a repository of personal narratives of biophysics educators at PUIs (including the full narratives summarized here) on the PUI Forum website hosted through the Biophysical Society (10); additional contributions are welcome. The goals of the repository and this report are (a) to share the cross-disciplinary and manifold nature of how the pandemic impacted teaching and research activities of educators in the cross-disciplinary educational landscape at PUIs and (b) to disseminate lessons learned prompted by the pandemic to enhance the educational experience of undergraduates.

Teaching at PUIs: on the switch at the start of the pandemic

Faculty teaching load at a PUI is typically 2 to 4 courses per academic term with class sizes of 10 to 200. During the sudden switch to emergency remote learning by the beginning of the pandemic-related lockdown in spring 2020, institutions adopted online synchronous and asynchronous classroom and lab teaching modalities. The key concerns that guided the choice of educational strategies and supporting technologies during this transition phase aimed at helping students achieve the core learning goals. Some personal examples are illustrated below.

A common strategy for adaptation in this rapid transition phase was to increase the use of technologies that were already in place to facilitate online work:

> During the pandemic's sudden lockdown period, I taught PHYS391, a 3-credit-hour, upper-level biophysics course, by adopting the *Physical Biology of the Cell* textbook (11). Originally, on-campus class sessions of this course included discussions of textbook material perceived as difficult as well as problem solving with students working in groups (12). I realized that I could not reproduce these in-class activities in a fully online setting because the problems required lengthy solutions with the need to look up previous steps. Moreover, most of my students do not possess a writing tablet that would allow them to write on an electronic whiteboard. For the second half of the semester, I expanded the use of the social learning platform Perusall (13, 14) that was designed to get students ready for class for the following reasons: (a) to motivate students to complete the reading assignments, (b) to allow me to see their difficulties, and (c) to asynchronously interact with my students. Additional online synchronous sessions were helpful to directly clarify student questions on the problems sets.

> Knowing that course-based research experiences can significantly help undergraduate students grow (15), during the second half of the semester I also piloted a limited-scope research project on DNA structures that could be carried out entirely remotely. The ever-increasing number of online data banks (e.g., Protein Data Bank (16), BindingDB (17)), tools, and software (e.g., UCSF Chimera (18), AutoDock Vina (19)) that are freely available for students and personal computer power make projects more accessible to undergraduate students working remotely. Because this project was introduced abruptly mid-semester, I chose (a) a topic that came somewhat naturally from previous class discussions and (b) an approach that allows for collaboration and division of labor as well as results to be obtained by finals week. (Christos Deligkaris)

The pandemic situation also required extra adjustments from faculty who were experienced in online course content delivery:

> My teaching style uses a flipped classroom approach. The benefits from a flipped learning model had been shown before (20, 21) and became even more apparent during the global pandemic (22). Therefore, when my institution switched to online teaching, students were used to watching videos before coming to class. The challenge I had was to translate the in-class activities to the online environment. To tackle this, I organized the interface of my courses better in the learning management system and added explicitly the learning objectives for each week. Although this was an effective approach, it does require a significant amount of effort from the instructor (23). This approach helped students to gauge their own learning as the course progressed and therefore prepared them better for exams. Engaging students in online synchronous classes benefited from my previous training using Zoom. I implemented the think-pair-share methodology (24, 25) using breakout rooms to help students develop the skill to ask questions in an online environment. Interestingly, students expanded their range of interactions while they were randomly assigned to short breakout sessions instead of self-selecting their partners (as usual in the classroom). During teaching and research office hours hosted via Zoom, students were engaged in quality conversations. In the future, I plan to continue this virtual office hour approach, as it allows me to reach a greater number of learners. (Yadilette Rivera-Colón)

On adaptations 6 months into the pandemic

Overall, teaching and learning experiences during the following pandemic semesters (fall term 2020 and following) were more positive than during the early lockdown phase, as students and instructors had adapted to the logistics and mechanisms of previously unfamiliar teaching modalities. Those included online-only, hybrid (simultaneous instruction for online and in-person students), and fully in-person approaches. Which delivery modes were chosen frequently depended on the local government, institutional policies, and instructor circumstances (such as health conditions). Two authors commented on their hybrid and in-person classes:

> Midshipmen (Naval Academy students) attended lecture and lab from academic spaces, not their living quarters. Class sections were split in half with groups offset weekly. While teaching a required introductory chemistry course for our freshmen class, my classroom was limited to the physical presence of 10 midshipmen and 1 instructor. For the hybrid model, 1 group of midshipmen was in the classroom with me, while the other was in a nearby classroom attending via Google Meet (26). This allowed all midshipmen to attend class each day in the hybrid academic space with socially distanced synchronous instruction. (Elizabeth A. Yates)

> I taught in a socially distanced classroom that included the requirement to wear masks and offered synchronous Zoom support for those students who needed to quarantine and were thus not allowed to attend in person. I made extensive use of the learning management system to deploy weekly, low-stakes assessments and formative feedback to inform progress toward learning outcomes. (Patricia Soto)

Some institutions were not able to offer laboratory classes or other practical learning experiences that are usually taught in person, and instructors were thus forced to employ unusual educational strategies. One author writes about the pivot to virtual labs and take-home lab kits as safe alternatives to traditional synchronous face-to-face labs:

> I have been tinkering with the use of virtual lab activities (27–29) and customizable, recyclable, and institutionally maintained take-home lab kits (30) in my chemistry and biochemistry courses. While assessments suggest that both virtual labs and take-home lab kits are suitable substitutes for face-to-face labs when in a tight pinch, virtual labs start to flounder when it comes to the tactile authenticity and open-ended inquiry that best engages students (31). Though take-home lab kits offer more tactile authenticity than virtual labs, asynchronous online implementations reduce the quality of peer learning and student–instructor interactions to the detriment of the least independent student populations (e.g., freshman) (30). I urge instructors to be particularly attentive to the needs of social learners and try to maintain high-quality peer-learning and student instructor interactions whenever possible. This would include implementing both virtual labs (29, 31) and customizable, recyclable, and institutionally maintained take-home lab activities (30) in a synchronized manner. Asynchronous discussion forums (e.g., VoiceThread (32)) and take-home labs can, however, still be useful for more independent learners with busy schedules. (Kambiz M. Hamadani)

Another author writes about integrating socially distanced experiments with online pre-lab materials for a laboratory practice course:

> Students watched online pre-lab lectures and instrument demonstration videos rather than getting that instruction in person as I had done in previous iterations of the course. This way, the students could pause and rewind pre-lab instruction while watching on their own time. I plan to keep using those materials for future iterations of the course. The students signed up for dates to complete up to 3 experiments on campus, with 2 or 3 students working in the lab each session, physically distanced from each other, the TA, and myself. (Jefferson Knight)

Thus, we find that instructors were able to use the time between spring 2020 and fall 2020 to effectively adapt their courses to a variety of different circumstances.

Lessons learned on biophysics teaching at PUIs

A recurrent theme that emerged in terms of course design and disaster preparedness was to consult instructional designers where available or connect with peers who have already organized their courses to be better prepared for the next crisis. In retrospect, we identify the following learning messages for future teaching under emergency conditions, which should be broadly applicable at institutions of higher learning:

- Design instruction delivery and curriculum with modularity and flexibility, using the course learning outcomes as the guiding backbone (33). Use assessment tools consistent with course design (34).

- Be flexible about your learning management system by building a toolbox of teaching resources and approaches (video recording, videoconferencing, shared files and whiteboards, discussion boards, collaborative annotation tools) that can allow pivoting when unforeseen circumstances arise (35).

We recognize the extra demands on course design these learning messages require. Yet we foresee gains in terms of developing more flexible courses with a larger toolbox of teaching resources (36), which promises additional benefits in terms of student growth and learning. Moreover, we envision such adaptations rendering our teaching more sustainable and aligned with the principles of inclusive teaching (37) when unexpected disruptions arise (38).

Research and research mentoring at PUIs: on the impacts of campus closure

Expectations on scholarship for tenure and promotion are different at each PUI. Some PUIs require authorship of peer-reviewed articles, and many require faculty to mentor undergraduate projects. Some institutions expect internal grant applications, while others expect external funding. As a result of the closing of campus in March 2020, the authors acknowledge that productivity in the research lab slowed or stopped in spring 2020. Yet some authors report that they were able to make progress in science writing:

> As a laboratory biophysical chemist, my research lies on the benchtop, but the transition back into my lab has been much slower than I anticipated. With limited research hours due to COVID-19 restrictions of my institution and collaborator, my research has been significantly impacted. One positive aspect I took advantage of was my ability to write, either from home or my office. I was fortunate to telework with my research collaborator and continue 3 projects that have led to 2 publications in 2020, with 1 forthcoming in 2022. (Elizabeth A. Yates)

Other authors, however, caution that the notion of productivity with respect to remote research and science writing may imply more complex considerations:

> While the COVID-19 pandemic has affected almost all aspects of our daily lives, the overall impact on faculty research is still not well understood. As a laboratory scientist, I need to go into the laboratory to take data. Yet this was not possible during the campus-wide shutdown that closed my laboratory for 7 months. This type of lab closure, along with conference cancellations, loss of institutional revenue, and reduced experimental access, has been documented (39), but loss of productivity is harder to measure. Submissions to journals in some fields spiked during the pandemic (40, 41), as did preprints on various arxivs (42). Yet some fields did not report these spikes (40), and others reported that journal submissions were disproportionately from men (42–44). I find that as a woman biophysicist, my productivity was much more complex than these numbers suggest. Yes, my time on the job decreased and my caregiving responsibilities increased, but my ability to prioritize tasks, drop tasks, and delegate tasks increased. With most social aspects of my life removed, I found myself working, tutoring, making dinner, and falling asleep with the kids! (Ashley R. Carter)

> My institution—a PUI that is also a Hispanic-serving institution—has mounted a very thoughtful and cautious response to the pandemic. Beginning in mid-March, all on-campus research activity was put on hold. Students and faculty checked out distance-learning equipment needed for instruction, and nearly all research pivoted to manuscript preparation or garage science. My NSF-funded project aiming to develop hands-on virtual/mixed reality

> science labs (45) was significantly hampered due to the lack of synchronized face-to-face real-time interactions between research personnel. (Kambiz M. Hamadani)

Although some faculty had the means to engage in scholarship even during a lab closure, others faced challenges derived from their homebound demands and the large investment in the adaptation of all their teaching load to a remote format.

By summer 2020, many research institutions were opening their laboratories back up, but the speed of transition back to in-person research labs at PUIs was unique to each institution:

> In July, faculty were allowed back on campus to prepare for restarting research. In September, on-campus research activities were allowed to return to 35% of normal capacity. Unfortunately, the resurgence of COVID-19 infections this winter has stalled hopes of continued increase in on-campus research activities. (Kambiz M. Hamadani)

Because summer is when the bulk of research activities occur at PUIs, these lab closures required faculty to engage students in research through different modalities:

> When research labs closed in the spring, I transitioned some of the undergraduate and master's research students who joined my lab over winter break into working remotely on projects in which data needed to be analyzed or papers written rather than new lab-based projects that they had started just before the pandemic. Later, as the lab reopened for one person at a time, I recorded videos of myself demonstrating some of our commonly used lab techniques, such as running gels and using particular instruments, to provide at least some practical training for my mentees. (Jefferson Knight)

> At my institution, students were not allowed to be in research labs. Therefore, we switched all our projects to be computer based. In some cases, projects already had a computational component, so the transition was smooth. At times, we had to rethink the project to make it computationally doable. For example, a student was conducting PCR mutagenesis to generate mutations to the active site of an enzyme to see how it would affect specificity. Instead, we looked at the proposed mutations and hypothesized possible changes using the software Maestro. We performed docking experiments of the substrates on the mutated proteins. All the software that we use is free and open source, so students could access the software from their laptops. In some cases, I made video tutorials that illustrated how to use the software to guide students' projects. (Yadilette Rivera-Colón)

> Ours is a computational research group; however, it was not possible to access our high-performance computing resources. We thus adjusted the goals and techniques of our projects: our group learned to use structural bioinformatics techniques that can be run on personal laptops and on online servers. (Patricia Soto)

These different modalities depended on the type of research and required individual faculty mentors to adapt using the resources available. Authors also observed that although faculty found ways to engage students in research and social connections, students with prior lab training were able to work in the remote environment much better than new students, especially in the case of benchtop research groups:

> Some found that remote data analysis, journal clubs, and science writing were beneficial during the pandemic (46), and others welcome the explicit acknowledgment that these activities "constitute research" as much as running experiments (47). However, I found that it

is important for new students to have an in-lab experience even if they don't do any lab work. Students who had 2 weeks of in-lab training, without any actual experimental work, were able to navigate remote work much better than brand new students. New students found it hard to talk to others in the lab, to manage their time, to figure out lab culture, and to ask questions. It turns out that a shared experience of working together in the lab is necessary for student growth. (Ashley R. Carter)

For some practitioners, online lab work became impossible. One contributor to this manuscript is a master's student whose planned research was severely disrupted by the pandemic:

I am a molecular biologist and a master's student in bioengineering. I came to Lithuania from Istanbul, Turkey, as an Erasmus+ trainee. I had great expectations for this internship. Most importantly, I wanted to carry out biophysical experiments in the lab. Unfortunately, these plans all changed once the pandemic struck. Within 5 days of my arrival to Vilnius, a nationwide lockdown and quarantine was implemented. For several months, I was living in the dormitory unable to do anything. (Duygucan Gül)

Implications for participation in meetings and conferences

One of the few positive developments during the pandemic was the trend to host online conferences, which were more accessible to people at PUIs who teach or take classes during the academic semester (48). Students and faculty presented their research at virtual events, and undergraduates gained experience in discussing posters and delivering remote oral presentations:

My students and I have enjoyed presenting our research at virtual events. (Jefferson Knight)

The modality of virtual conferences enabled undergraduates and me to present our work in the fall semester (at an international conference, a topical conference, and an undergraduates-only conference). (Patricia Soto)

One author also stated that multitasking was easier during online meetings:

There are a lot of mixed messages on whether multitasking during the pandemic was more or less productive (49–52). However, I will note that it is much easier to multitask if you have an online meeting rather than an in-person meeting. Usually, I ran outside during meetings and pushed my daughter in the stroller! This was a great way to get exercise while having long conversations with a single student or maintaining focus in large-group meetings where I did not have a speaking role. (Ashley R. Carter)

These online events have also been helpful to postdocs who are interested in faculty positions at PUIs:

It is clear that postdoctoral fellows feel the overall negative impact of the pandemic massively, be it hiring freezes, raise freezes, the lack of support, or the slim chance of finding a permanent academic position. I personally tried to take time for my mental health; I feel lucky to have a supportive principal investigator and colleagues that help me grow. A good support system is really important in ways that become especially apparent in a time of crisis such as this pandemic. I also took advantage of several online events for career development and community building. I learned a lot while staying motivated and connected during this

challenging time, especially thanks to the Education Committee and the PUI Network of the Biophysical Society. (Tugba N. Ozturk)

Online events provided undergraduate students with opportunities to develop their communication skills in a digital environment, and the authors of the report benefited from newly formed online communities spurred during the pandemic.

Lessons learned for research and mentoring practice

On reflection, we find the following learning messages valuable when planning, designing, conducting, and evaluating undergraduate research under pandemic conditions:

- The pandemic constraints prompted faculty to be more creative about how they design undergraduate research experiences (38), including tweaking the perspective and scope of research projects.
- When moving students to online research projects, faculty are advised to carefully craft strategies to connect with students and to forge a sense of community.
- Online conferences and meetings were valuable for PUI faculty and students who have difficulties traveling during the semester.
- We suggest assessing the undergraduate research experience using not only standard bibliometrics (53) but also metrics of multidimensional student growth (54), such as the researcher skill development framework (55), adjusted to the particularities of the PUI environment.

Final reflection

From the ongoing pandemic, we have learned to celebrate the differences and creativity that each of us have used to respond under these extraordinary circumstances. We recognize that there is no "one size fits all" recipe to tackling the situations that arise. The pandemic prompted innovations that required agility on the part of each practitioner to adapt courses and research programs quickly, consistent with the institutional mission and values at each PUI, as well as homebound responsibilities.

Looking ahead, we expect this report to inform our practice as we learn to live with the coronavirus. What is novel for some may be common practice for others. Indeed, several learning and research tools that were sparsely used prior to the pandemic have already become common. In sharing our perspectives, we hope to move the biophysics education community forward in a manner that embraces the differences in educational practices and fosters appreciation for the unique challenges that each educational work environment faces.

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