Benore Marilee (Orcid ID: 0000-0001-5814-4910)
DRIES DANIEL (Orcid ID: 0000-0002-0530-5212)
Provost Joseph (Orcid ID: 0000-0003-1487-1459)

INTRODUCTION: The 2020 Covid-19 outbreak prompted institutions of higher education to rapidly provide remote options for instruction. Faculty around the world have been, rather suddenly, required to move their teaching online. Recognizing the need for support during this unexpected transition, a group of experienced faculty came together to create biochemistry- and molecular biology-specific recommendations and provide resources to support the community during the shift to remote learning. This team was composed of individuals with extensive experience teaching online, educational/pedagogy experts, and experienced faculty from a range of backgrounds and institutional contexts. The guidelines and resources reported here are supported by the literature and/or team members' extensive experience with online learning.

The American Society for Biochemistry and Molecular Biology (ASBMB), a long-standing and vociferous advocate of life science education, played a key role in supporting this effort by hosting the information on their website (ASBMB, 2020). This dynamic webpage of resources for biochemistry and molecular biology (BMB) classrooms and teaching labs includes an open invitation for instructors to continue to contribute to this list, making this resource an evolving, community-driven source of knowledge.

The goal of this work is to provide a starting point for instructors as they revise their course design for remote education. Instructors that are new to teaching online will find methods to evolve their instruction as they become familiar with the mechanics and technology of teaching remotely. This document also includes specific advice for those needing to create a virtual, remote biochemistry or molecular biology laboratory. Depending on the instructor's experience, institutional resources to support moving instruction online, and the level of engagement of students, some practices may be more effective for a particular situation than others. At the time of this writing, the world is in the midst of a pandemic; however, it is important to recognize that institutions have faced disruptions before, from natural disasters such as flooding, hurricanes, and even fires. Thus, instructors need to have a plan on hand to adapt their teaching, engage students, and provide structure and continuity while the physical site of a university is closed.

Additionally, while this resource was generated in response to a global pandemic, the resources and promising practices described here will likely be of interest to instructors seeking to refine and improve the student experience in their courses. We anticipate that, when the community returns to the classroom, they will be enticed to adopt lessons learned from remote teaching to reinvent their face-to-face teaching into more blended learning environments. Therefore a secondary goal of this article is to expand the teaching toolkit of BMB educators to invigorate their teaching and actively engage students in their learning.

The following resource includes guidance for instructors, from the basics of designing your online course to a discussion of the typical types of assessments employed in remote

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instruction. Suggestions for collaborative class activities and alternatives to in-person laboratories are included to help foster an online community during this time of disruption and beyond.

ORGANIZING COURSE MATERIALS AND COMMUNICATING WITH STUDENTS

Optimizing your Learning Management System (LMS): When considering the organization of your course, think of the key learning outcomes/objectives you already have in place (Anderson, 2008). Drill down to the most critical and essential learning outcomes and use these as your guide. It is easy to focus on how to deliver the content, but don't lose sight of the larger goals for your students - the outcomes you've already created when designing your course. Take the "backward design" approach, starting with the outcomes, how you want to cover this, and then think about the technology that will help you achieve these goals (e.g., Wiggins and McTighe, 2005; Handelsman et al., 2007).

Use your existing syllabus to pinpoint and create content areas that are readily identifiable to students. For example, if your syllabus indicates that the next three lectures are focused on lipid metabolism, then create a content area with that same title, and keep all resources associated with those lessons together. Providing the students with a guide for where to find everything within the LMS in a "Navigating this Online Course" section is helpful. This can be sent to students as an email, or placed in a "Start Here" content area on the LMS. If you have screen recording software, you could even walk your students through the course setup and post a welcome video.

Communicating with Students : It is tempting to think that students will find the transition to remote learning intuitive. Yet, it is likely our students will be finding the transition as bumpy and distracting as we do! Err on the side of over, rather than under, communicating with your students. Identify official channels for communication; for example, encourage your students to enable notifications from your LMS, or to check for new announcements and course materials daily. Some students will opt out of LMS notifications to keep their inbox from being flooded. Make it very clear how you will communicate: a Monday announcement summarizing the week's activities can be useful.

While communication is key, students displaced during the pandemic may not have access to the same infrastructure for distance learning that they would in their native campus environment. Consider surveying students about their access to technology and the available ways to communicate from a distance. This will help you understand the potential barriers faced by students in your course and devise the most effective strategies to mitigate them. Let

students know in advance the multiple ways that they can reach you if they are facing challenges in meeting course expectations. Remember that you and your students are navigating unanticipated and uncharted waters and, unlike faculty, students likely haven't had the benefit of peer support or tutorials to help them figure out quickly how to adapt to remote learning; they will need clear and structured guidance from you. For example, for students who anticipate having unstable internet connections, it may be advisable to provide access via text messaging for rapid real-time communication when other modes of communication fail. This can be done without sacrificing privacy by using various apps (e.g., Remind, Slack, Google chat, GroupMe). Alternatively, you may be able to forward office calls so students can reach you by telephone without making a personal cell phone number public.

Equity: It is unreasonable to assume every student has access to the same tools for learning. Some students may have vacated campus for spring break, not anticipating the inability to return, and therefore may not have access to basics like their textbook. Similarly, dedicated access to a computer or high-speed Internet in a distraction-free environment may be a stretch for students sheltering at home or in rural areas. Given the likelihood that students will have variable access to necessary resources, anticipate the ways in which you may need to be flexible and the ways that your students will interact with your materials. *Simplify*: both for your students and for yourself, and consider using materials that students are already familiar with (i.e., using a current online homework system for quizzes or exams) so that there is not a steep learning curve on software or a complicated set up. Before you invest yourself in new tools and gadgets, consider how you will grade assignments and how long it will take to get them back to students to improve their learning and understanding. There are a lot of options for online learning platforms; choose one and stick with it.

Office hours: Vary the times you're available, but maintain control of your time. It is easy to expand to help all students one-on-one and find your own time has evaporated. Ideas for interaction include: 1) open LMS- (or Zoom)-facilitated live sessions, 2) a recorded test review, 3) message-based chats (e.g. through Google chat), 4) a calendar reservation application (i.e., www.reserveme.com or through Google calendar) that allows you to designate times during which students can schedule 10-20 minute one-on-one meetings.

COURSE CONTENT: BORROW, ADAPT, OR CREATE?

Creating your own content is invigorating, and best done with some careful deliberation and planning, including scripting and choreography. However, detailed planning may not be a luxury you have at this time, and, if you are unfamiliar with content creation, this could be quite a hill to climb. Therefore, this team recommends those unfamiliar with creating content to *outsource*

your content at first, so you can spend time planning interactive assignments and working on your course assessments. There are wonderful resources and talks from experts available online, and we have aggregated links that you can use from resources you can lean on, including ASBMB. Did you find a video on a topic you need to teach, but it contains an error? Use this as a teaching tool. Your LMS will have a way for you to provide a description of the resource, and you can provide students with the timestamp and explain the error.

For those familiar with content creation, be sure to create small bites of content based on the learning objectives that you have already streamlined. Think about the multiple topics that you would cover in a standard lecture period and create content for those topics separately. Linked within the ASBMB website (ASBMB, 2020) there are several content links for you to use, including a comprehensive set of lecture videos from Professors Pratt and Cornely. Consider how you will ensure that students are working through this material in a timely manner (i.e. quizzes and/or homework assignments with specific deadlines). There will be a fine balance between flexibility, especially for students with slower technology or limited access, and making sure that students are making progress.

Most LMSs have limited space for uploaded content; however, YouTube is an excellent way to deliver videos to your students. When you upload, there will be an option for your video to be **unlisted**. This means that only individuals with the link can view it, and you can provide this link to your students through the LMS without it being able to be viewed publicly.

ASYNCHRONOUS DISCUSSIONS / DISCUSSION BOARDS

Social distancing practices may promote feelings of isolation, so focus on ways to engage your students in a collaborative discussion. Students can discuss practice problems (to save time, you might assign some from the text or re-use existing problems you have). Your textbook may also come with online resources you can use to facilitate discussions. Be clear on your expectations for participating in discussions and how students will be evaluated (if at all). To minimize academic integrity issues, consider evaluating students on how well they collaborate in the discussion (by number/content in posts) rather than how correct the final answer is. That being said, if the correct answer is not heavily weighted, you can feel free to use this as your teaching time, guiding students toward the correct answer once they've grappled with the problem for an appropriate amount of time.

The discussion tool in your LMS can also be used to promote self-regulated learning and community. Create a discussion thread entitled, "Urgent questions" or similar. As the instructor, post questions you are emailed, along with the answer, so that all students can benefit from the

information. Encourage students to use this thread to post and answer questions about technology or course material. Set expectations that students should be playing the vital role of "first responders" to any question that is asked; you may even incentivize this with a participation grade. Often students can help each other and gain confidence in their abilities to navigate the content within the online environment. You can then review student questions and responses, and affirm or clarify as needed. This method significantly lightens the burden on the instructor, who may feel like they need to check the online space continuously.

COLLABORATION AND PEER REVIEW

Collaborative projects and peer review are still possible at a distance. Begin by considering what interactions absolutely must be synchronous. Given the likelihood that students will be accessing from various time zones and with unstable connectivity, it will be likely that at least some activities will need to be adapted for asynchronous interactions.

For synchronous activities, set break out rooms and set up times to meet virtually (using your LMS to have a non-recorded meeting without you), or allow students to gather to work on Google Docs/Sheets/Slides, Facetime chats or LMS-mediated collaborative events. Synchronous meetings with the instructor can be used to have each group report out and give feedback. Recorded mini-presentations from students could also be employed to evaluate asynchronously.

Some who use **peer evaluations** in their face-to-face classrooms may want to do more of the same for group activity (Tenorio *et al*., 2016). In many ways, this is a mechanism to help students to be connected and create a culture of learning. Studies indicate that active participation in collaborative learning correlates with learners' satisfaction (Wen and Tsai, 2006; Kulkarni *et al*., 2013).

ONLINE ASSESSMENTS

You may be thinking, "I can certainly deliver content and engage my students at a distance, but how do I accurately assess their learning?!" Some institutions may already subscribe to a video proctoring service. These services often charge by the assessment and therefore can be quite expensive, so they might be best employed for final exams only, and not each and every test. Every LMS has the option to build a test, quiz, or assignment. If you already have a large bank of assessment items, you can load them into your LMS and auto generate a quasi-unique assessment for each student (Gikandi, Morrow & Davis, 2011).

The first assessment of every semester is anxiety provoking for students in part because students must familiarize themselves with the modes of assessment for a particular instructor and course. Many students will be unfamiliar with the technology needed for online assessment, and will therefore benefit from an opportunity to become familiar with the new format of a quiz or other evaluation. Therefore, we recommend a practice quiz to help them get used to the format (Cassady & Gridley, 2005). Alternatively, the first quiz (or new assignment type) can be worth fewer points than a typical quiz will be. This allows the student to become comfortable with the new tool in a lower-stakes environment.

As an instructor, you may be concerned about issues related to academic integrity, particularly given the myriad repositories of archived course materials available to students (e.g., Chegg, Course Hero). For each of the assessments below, we provide points of consideration for minimizing the potential for violations of academic integrity.

Assignments can be created to assign the students projects, papers, and problem sets. These are done at the students' own pace, and are usually submitted individually. Often, the LMS will have a built-in plagiarism tool (e.g. "SafeAssign" in Blackboard). Rubrics for grading can be entered into the LMS system. Rubrics serve a dual role of clearly communicating the expectations and evaluation criteria to students, as well as a tool for streamlining grading. The LMS rubric provides selection of various point scale options that can be opened while viewing an individual student's assignment and "click" selection of the scale level of correctness for each question or section. The rubric will automatically total points for the entire assignment and transfer the score to the gradebook.

Take home exams are a possible option for evaluation where students have open book/open resources. They can allow flexibility for when the student works on the exam, and they don't require extended reliable internet access. In order to minimize academic integrity issues, consider reserving take-home exams for assessments that require students to evaluate and/or synthesize information (Sheard *et al*., 2017).

Quizzes and tests These may have a time limit and can include essay questions, numeric responses, file uploads, multiple choice questions, multiple answer questions, and much more. Other setting options often include showing only one question at a time as students complete the test, randomizing questions and/or answers, not allowing a student to return back to a prior question, etc. These LMS assessments are useful for evaluating a student's understanding following a discussion or activity. Multiple choice and multiple answer questions are self-grading, making this a good option for larger courses. Again, consider initially replacing your

regular exams with several mini-exams to ease technology, student anxiety, academic integrity issues, etc.

Quizzes can be set up to give multiple attempts, which is useful for students who have unstable internet access and may have their assessment interrupted unexpectedly. If you have a large question bank from years of teaching a course, you can upload them into a question pool from which the LMS draws to generate the quiz (Sheard *et al.*, 2017) . In this manner, academic integrity issues can be minimized because the student is less likely to encounter the same question twice. You can set the LMS to score the question using an average, highest grade, or most recent attempt. For a timed test, it is advisable to set up the test in a way that allows some flexibility for difficulties with technology or internet connectivity.

Most LMSs allow **adaptive release** of course materials, which enables the instructor to open course materials sequentially, once a student has interacted with another item in the course. For example, you can allow a test to open only after a student has opened the instructions, or release the next course lesson only after a student has submitted a particular assignment.

Discussions can be used as a tool to engage students and as an assessment (Arend, 2009; Vonderwell, Liang and Alderman, 2007). Consider this as a substitute for a participation grade, if you have that in your syllabus. Perusall (http://www.perusall.com) is a free web-based tool that allows an instructor to post a reading or link to an electronic textbook and invite students to post comments and questions directly in the PDF (Lee & Yeong, 2018). It has an auto-scoring function which does a reliable job of grading the quality of the contribution to the discussion. This was originally developed by Eric Mazur of *Peer Instruction* fame and is now utilized by many instructors to engage students in reading and critiquing primary literature (Maxur, 1997).

ONLINE LAB WORK

Lab courses are one of the more complicated and difficult spaces to recreate or instruct through remote learning. Accept that the lab bench experience cannot be fully reproduced. Again, this is something that can be backward-designed. Start with the key learning objectives, and let that drive your decisions. If data analysis and critical thinking are part of your laboratory class outcomes, ensure they are built into the design of your lab course—and let yourself be creative and imperfect in design of the class.

For lower level laboratories, are there simple experiments that can be conducted at home? Depending on the number of students, mailed pH strips and household items could be used in a titration. Alternatively, consider finding a virtual simulation from the many collections on the

Internet. We all know making solutions and buffers are the bane of biochemistry students - so think about designing learning activities on these subjects.

Deep analysis of the literature is also an excellent way to build laboratory-related skills. Access a *Journal of Biological Chemistry* article and have the students review the methods sections - they can create presentations on various aspects of the methods of a few key papers and analyze the figures and results sections in a follow-up activity.

Demonstrations are very valid when in a pinch. You could create a video of a technique and annotate the key steps of a western blot, an SDS-PAGE gel, or protein assay, or keep your teaching assistants employed by having them create videos or demonstrations. Include simple quizzes to keep students engaged. Walk students through an enzyme assay and record the assay being conducted - perhaps even do this live in a Zoom or WebEx chat or using the meeting features in your LMS. Show the spectrophotometer as absorbance changes to talk about reactants and products. Pause and interact with the students, have them break out into groups (if your LMS allows) and make predictions on the experiment at hand. Then give them data sets to analyze. You might assign different data sets for different student groups, perhaps some that have a "flaw" and a follow-up repeated experiment. If you don't have access to laboratory videos, there are some resources linked through the resource webpage (ASBMB, 2020).

Biomolecular modeling is another interactive option. Using Chimera, PyMOL, Jmol or other visualization programs, you can design experiments where students are asked to model active sites, mutate amino acids, and consider the effects of a proposed mutation. There are RNAseq and protein mass spectroscopy databases that can be mined for hypothesis-driven experiences. Free programs exist to modify a PDB file and predict protein or ligand docking and energy minimization. Ask students to make predictions and conduct a virtual experiment based on a PDB structure. You can take advantage of many online tutorials in this area; there are several linked examples of these in the resource list.

Shared Data Sets If you can use data sets from your prior labs, your personal research or that of a colleague, you can set up the kinds of virtual labs discussed here. Two specific examples linked below that focus on protein biochemistry are the *Malate Dehydrogenase CURE Community* and *BASIL* virtual protein lab groups. Both have plans for running parts of a semester in virtual format using existing shareable data. CourseSource and CURE.net are other possible sources to find labs with data to convert to this format.

You could also consider having students work on a ***grant proposal*** as an alternative to wet lab techniques. Students will gain experience in formulating hypotheses, experimental design, and literature analysis. They can learn about techniques and instrumentation that they might not have available to them in the laboratory.

Finally, think of all of the times you've taught a laboratory and wished there was more time to have students really think about their results. Why not have them go back and be critical in their analysis? Now you have time to do some very valuable teaching to the students.

FINAL CONSIDERATIONS

Remain focused on your students as you make the transition to online. Be knowledgeable about what your school is doing or planning to do to accommodate students without technology access, and serve as conduit of that information to your students. Student access to the internet is only one question to think about. Will they need to have a working printer? A phone to photograph/scan their work? Will students be able to do the testing or attend synchronous LMS sessions if there are other siblings or parents using the only computer? Does your school have a laptop check-out program, or emergency loans available? Can you give students the flexibility to work on class items in a given time range?

Practice your plans to assess with a low points/stake quiz using the same plans as the full test. Find the glitches before the assessment is "live".

Collaborate with your colleagues near and far. Can you combine exam questions with a colleague in your department teaching the same class so that you have a bigger pool of questions in your LMS assessments? Can you open your office hours to all students taking the same classes within your department so that students have more time options?

Know if your school is allowing *changes to course syllabi* or outlines as you transition online. If so, distribute through multiple avenues (i.e. email, LMS posting, etc.) a copy of the modified syllabus/outline to all students and be clear about the changes. Invite students to ask questions about any aspect that is not clear or they have concerns about.

Finally, *be flexible.* Recognize that disruptions may happen and that your strategies may not go exactly as planned. Even if this is not your best course ever, your commitment and compassion will go a long way in helping your students achieve acceptable learning outcomes. You and your students are all in this together, and you will succeed together, too.

CONCLUSION

A webpage of resources to support BMB instructors transitioning to remote teaching has been created in response to the disruption of our physical classrooms. This collaboration with ASBMB is intended to be a community-driven resource, and we invite the broader community to utilize this tool and contribute links that may be helpful to other instructors. Because of their support we would like to acknowledge and thank the ASBMB for providing this and other educational resources supporting the biochemistry and molecular biology community. This along with many other examples including an education focus in the Annual Meeting. As we work together to meet the challenges brought by the disruption of our physical classrooms, we are hopeful that this experience, though abrupt and taxing in this moment, will bring positive shifts in pedagogy as we move forward. We may come to discover that one unanticipated benefit of the pandemic-induced transition of face-to-face courses and labs to remote delivery will be increased use of technology to enhance student engagement and learning when instructors return to their physical classrooms. And perhaps many of us will return to the physical classroom as better, more resilient, instructors than when we left it.

Anderson, T. (Ed.). (2008). *The theory and practice of online learning*. Athabasca University Press

ASBMB 2020, Online Teaching: Practices and Resources, viewed 26 March 2020 <https://www.asbmb.org/education/online-teaching>.

Arend, B. (2009). Encouraging critical thinking in online threaded discussions. *Journal of Educators Online*, *6*(1), n1.

Cassady, J. C., & Gridley, B. E. (2005). The effects of online formative and summative assessment on test anxiety and performance. *The Journal of Technology, Learning and Assessment*, *4*(1).

Gikandi, J. W., Morrow, D., & Davis, N. E. (2011). Online formative assessment in higher education: A review of the literature. *Computers & education*, *57*(4), 2333-2351.

Handelsman, J., Miller, S., & Pfund, C. (2007). *Scientific teaching*. Macmillan.

Kulkarni, C., Wei, K. P., Le, H., Chia, D., Papadopoulos, K., Cheng, J., Koller, D., & Klemmer, S. R. (2013). Peer and self assessment in massive online classes. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *20*(6), 1-31.

Lee, S. C., & Yeong, F. M. (2018). Fostering student engagement using online, collaborative reading assignments mediated by Perusall. *The Asia Pacific Scholar*, *3*(3), 46-48.

Mazur, E. Peer Instruction: A User's Manual. Pearson Series in Educational Innovation: Instructor Resources for Physics. Upper Saddle River, NJ: Prentice Hall 1997.

Sheard, J., Butler, M., Falkner, K., Morgan, M., & Weerasinghe, A. (2017, June). Strategies for maintaining academic integrity in first-year computing courses. In *Proceedings of the 2017 ACM Conference on Innovation and Technology in Computer Science Education* (pp. 244-249).

Tenorio, T., Bittencourt, I.I.,Isotani, S., and Silva, A.P. (2016) Does peer assessment in on-line learning environments work? A systematic review of the literature. *Computers in Human Behaviour,* 64, 94-107

Vonderwell, S., Liang, X., & Alderman, K. (2007). Asynchronous discussions and assessment in online learning. *Journal of Research on Technology in Education*, *39*(3), 309-328.

Wiggins, G., Wiggins, G. P., & McTighe, J. (2005). *Understanding by design. Expanded 2nd ed.* Alexandria, VA: Association for Supervision and Curriculum Development.