When low and high tech solutions converge: Adapting to teaching soils during the COVID-19 pandemic

Michael L. Mashtare1,2,3 | Charlotte I. Lee1,4 | Sherry S. Fulk-Bringman1 | Erica A. Lott5

1 Department of Agronomy, College of Agriculture, Purdue University, West Lafayette, IN 47907, USA
2 Environmental And Ecological Engineering, College of Engineering, Purdue University, West Lafayette, IN 47907, USA
3 Currently with Agricultural and Biological Engineering, Penn State University, University Park, PA 16802, USA
4 ESE-IGP, Purdue University, West Lafayette, IN 47907, USA
5 Center for Instructional Excellence, Purdue University, West Lafayette, IN 47907, USA

Correspondence
Michael L. Mashtare, Agricultural and Biological Engineering, Penn State University, University Park, PA 16802, USA.
Email: mmashtare@psu.edu

Assigned to Associate Editor Colby Moorberg.

Abstract
COVID-19 restrictions required a transition of our Soil Science and Forest Soils courses to an online format. A pre-transition survey found that ~10% of students enrolled in our courses lacked high-speed internet capable of streaming videos and/or computers compatible with the applications in our Learning Management System (LMS). To ensure that students with limited internet or technology were not left behind, we adopted a low-tech/bandwidth delivery (slides + transcript with LMS-delivered assessments) of all lectures and recitation activities. Students could also complete either a low-tech/bandwidth (lab slides + transcripts) or high-tech/bandwidth lab option (delivered via video). Upon completion, students were surveyed to assess preferences and perceptions which are vital in understanding how our approach impacted student motivation, engagement with the material, and overall course satisfaction. Despite 90% of the students having access to high-speed internet, ~45% of the students used the low-tech solutions either exclusively or half the time, even when high-tech options (such as video) were available. Overall, students felt the low-tech/bandwidth delivery of the lecture (~87%) and recitation (~76%) material was effective. Students (~74%) also reported that online delivery of the lab material effectively supported their learning and was an effective replacement for the in-lab learning experience. Students preferred in-person to online delivery (63 vs. 17%) with 20% undecided. Noting the flexibility and organization of the course, 69% of the students felt the online delivery of our courses was more effective than their other courses despite, or perhaps because of, the lack of high-tech delivery. Our experience demonstrates one approach to adapting an in-person course to a virtual environment that considers inequities in broadband and technology access. Despite being perceived as effective by our students, low-tech options were less preferred than in-person instruction suggesting that, while effective, it was not viewed as equivalent.

Abbreviations: LMS, Learning Management System; SRC, Soil Resource Center.
1 | INTRODUCTION

1.1 | Background

Like many institutions of higher education, the date 13 Mar. 2020 served as a pivotal point at Purdue University in our instructional format. With a week’s notice, in-class instruction was migrated to online instruction campus-wide due to the COVID-19 pandemic. Concerned about accessibility, students in our Soil Science and Forest Soils courses were surveyed in lecture (n = 189, 100% response rate) prior to leaving campus to assess their access to high-speed internet and computing capabilities while off campus. This survey found that ~10% of our students indicated they did not have reliable high-speed internet access capable of streaming video and ~10% indicated they lacked access to a laptop or desktop computer (e.g., Windows or Mac OS) capable of utilizing some of the more advanced applications in our Learning Management System (LMS), Blackboard (Blackboard, Inc.). Students who said they had limited (or no) access to computers did not on their survey, or through in-person communication, that they could access basic LMS functionality using their phones or other basic devices (e.g., tablets or Chromebooks). This gap in access to technology was not surprising given that many of our students are from rural areas that lack stable, high-speed internet infrastructure and/or are from diverse socio-economic backgrounds that may limit their access to high-speed internet or computers in their home environment. In Indiana, for example, broadband access and computer ownership is lower than the national average (bottom half), with 17% of all residents lacking access to broadband internet with a disproportionate percentage (80%) of those residents living in rural areas, a trend consistent with other out-of-state rural communities (as reviewed by Lai et al., 2020). This led us to question whether migrating to a high-tech-intensive solution, such as WebEx or Zoom, would really be the best approach in serving all our students.

1.2 | Our course structure

This study centers on two introductory Soil Science courses taught in Spring 2020 at Purdue University: one focused on general Soil Science (n = 125) and the second focused on Forest Soils (n = 64). These undergraduate courses serve students primarily from the College of Agriculture, College of Engineering, and College of Science across all classifications (i.e., freshman, sophomore, junior, and senior). The format for both courses includes a weekly lecture to introduce that week’s material, a lab to promote depth of knowledge, and a recitation to help synthesize and reinforce understanding of the material. In Spring 2020, both courses shared the same instructor for lecture, with the only difference between the courses being the examples used to support, and provide context to, the lecture material. That is, although the overall content in both courses was the same, the examples given in lecture varied. For example, nutrient management (e.g., phosphorus deficiency) in the Forest Soils course might focus on conifers in the Forest Soils course, whereas the general Soil Science course might focus on corn. Lab and recitation materials, as well as exams, were identical for both courses. While there were five recitation instructors, all recitations were scripted and followed the same agenda, activities, and quizzes. All materials and assessments in the courses were tied to the course learning objectives.

1.2.1 | Prior to 13 March 2020, pre-COVID-19 instructional approach

Prior to 13 Mar. 2020, both courses were taught using an in-person Tuesday lecture, an open hybridized lab, and an in-person Friday recitation. The lectures used in-class worksheets, iClicker questions, Immediate Feedback Assessment Technique (IF-AT), fill-in PowerPoint slides, and demonstrations to actively engage the students as they were introduced to the weekly material. In-person, closed-book, closed-note hourly exams were also given during the lecture period. To help students prepare for the hourly exams, two evening in-person review sessions were offered before each exam. We also offered an online gamified exam review utilizing Quizizz (Quizizz Inc.) and practice exams. However, no practice exam keys were distributed. The open hybridized lab used a flipped approach that included closed-captioned video instruction which could be watched in or out of the laboratory. The video instruction included periodic in-video quizzing to ensure that students followed (i.e., actually paid attention to) and understood the video-delivered material. This was coupled with an in-person hands-on lab experience in the Soil Resource Center (SRC). The SRC was open ~40 h per week, offering the students the flexibility to come-and-go as their class, work, and activity schedules permitted. In the SRC, the students interacted with laboratory displays, activities, and experiments, and were provided with access to peer and instructional support by faculty, staff, teaching assistants, and undergraduate
**Course Structure for Soil Science and Forest Soils**

| Pre-March 13, 2020 (in-person) | Post-March 13, 2020 (online) |
|-------------------------------|-----------------------------|
| **Lecture (introduce weekly material)** | **Exam Review and Exams (review and assess)** |
| In-person Lecture with fill-in PowerPoint | Lecture slides (PDF) with transcript |
| worksheets | worksheets via LMS |
| demos | Participation “quiz” via LMS |
| iClicker | IF-AT |

| **Lab (depth of knowledge)** | **Recitation (synthesis and reinforce understanding)** |
|-------------------------------|-------------------------------|
| Hybridized (flipped) lab with video instruction and in-video quizzing | Instructor leads a discussion and activities focused on key learning objectives |
| Paper lab packet checked for completion in SRC | worksheets |
| In-person lab experience in the SRC - open 40 hours per week - (benchwork, experiments, demos) | drawings |
| Peer and instructional assistance/feedback on all deliverables | group work |
| Paper hand-in checked in SRC and reworked until correct | demonstrations |
| PDF and transcript covering key discussion points | closed book weekly quiz |

| **Instructor leads a discussion and activities focused on key learning objectives** | **Worksheets and activities delivered through the LMS, checked in real time with feedback provided so that students can re-work problems** |
|--------------------------|-----------------------------------------------------------------|
| worksheets | Open book/notes weekly quiz delivered via LMS |
| group work | |
| demonstrations | |
| closed book weekly quiz | |

| **Exam Review and Exams (review and assess)** | **Instructor leads a discussion and activities focused on key learning objectives** |
|-------------------------------|-------------------------------|
| Two in-person evening exam reviews before each exam + gamification + practice exams (no keys) | PDF and transcript covering key discussion points |
| In-person, closed book/note exam held during lecture | |
| Practice exam with key provided after uploading attempt to LMS + gamification | |
| Online, open book/note exam in LMS, one question at a time, randomized, three hours to complete once started, 24-hour exam window | |

**FIGURE 1** Summation of course structure before (left) and after (right) 13 Mar. 2020

In addition to completing their labs in the SRC, the SRC also provided students with one-on-one help (tutoring) on the course material. Students completed a weekly paper lab packet and weekly lab hand-in which provided an opportunity to apply key objectives from that week’s material. The weekly hand-ins were checked by the lab instructors/tutors prior to the student leaving the lab and they were encouraged to reread the hand-in, with guidance, until it was correct. At the end of each week, students attended a weekly recitation which was designed to help students focus on key objectives from the weekly material through iterative worksheets, demonstrations, quizzes, and group activities including drawing exercises and games. A synthesis of this approach is shown in Figure 1a.

1.2.2 After 13 March 2020, COVID-19 instructional approach

As our mode of delivery switched to an online format mid-semester, we recognized the need to adapt our approach so that our tech-limited students would not be disadvantaged. Thus, we adapted our course to include low-tech/bandwidth delivery of all lectures, lab, and recitation materials. Instead
of video delivery, in-person lectures were replaced with a PDF of the weekly slides and transcript of the lecture. A low-tech/bandwidth participation quiz (i.e., text-based with minimal images and no video) adapted from the planned in-class worksheets and iClicker questions was delivered through the LMS. The remaining hourly exam and the final exam were delivered through the LMS. The exams were open-book and open-note. To minimize the potential for cheating, the exams were delivered one question at a time in a randomized order. Once their answer for each question was submitted, students were not able to backtrack and change their answer. Students were given a 24-hour window to complete the exam and were given three times the normally allotted time to finish the exam once started. The additional time was intended to allow students the opportunity to overcome or adapt to challenges they may encounter when taking the exam online. Our hope was that this would compensate for distractions in their new work environments, such as noise or technological issues (identified by Fask et al., 2014; Hollister & Berenson, 2009), while addressing student concerns that online exams can be more time intensive than their equivalent in-person exams (Khan & Khan, 2019). In place of in-person exam review sessions, practice exams were sent out to the students via email and posted on the LMS. Our online gamified exam review remained accessible to all students (Quizizz, Inc.). Access to the exam keys were effort-based. To gain access to the exam key so they could check their work, students were required to upload their attempt on the practice exam to the LMS. Students were encouraged to reach out to their lecture or recitation instructor with any questions. While students could still watch the lab videos (and complete the in-video quizzing) if they chose, all students were also provided with a PDF containing screenshots from the lab video as a transcript as an alternative to the high-bandwidth video option. Students who used the low-tech option (PDF + transcript) were directed to complete a quiz through the LMS which included the same questions as the in-video quizzing. All benchwork materials that had been previously completed in-lab were converted into a digital (PDF) format which included photographs of all benchwork materials including step-by-step instructions, photos, and data from the experiments they would have conducted had lab been in-person. Lab packets were provided in a MS Word format and students uploaded the completed packets to the LMS to be checked for completion. Lab hand-ins were delivered via the LMS and offered immediate feedback and hints, as appropriate, upon submission. Students were encouraged to reread and resubmit the electronic hand-in until they received a perfect score. The in-person recitation periods were replaced with a PDF and transcript of the key discussion points, including practice problems, and the weekly activities and quiz were reworked and delivered through the LMS which provided immediate feedback and scoring. To maintain some sense of organization and normalcy, lecture, lab, and recitation schedules (days) remained the same as during in-person classes; however, the timelines of all deliverables were extended to account for different time zones and to increase flexibility. For example, if a student normally attended in-person recitation on Friday from 9:00 a.m.—9:50 a.m., this was replaced with a 24-hour window on Friday to complete their work once we transitioned to the online format. A synthesis of this approach is shown in Figure 1b.

To help students manage and navigate the format change: (1) students were provided with a detailed overview of the “new” online course format in their recitation sections prior to departing campus on 13 Mar. 2020; (2) email reminders were sent out several times per week reminding students of upcoming deliverables; (3) all materials (e.g., lecture PDFs and transcripts, lab packets, and supplemental readings) were sent out via email and posted to the LMS to increase accessibility; (4) silly/light-hearted jokes, puns, and other attempts at humor were interspersed in all email communications, lecture materials, and recitation materials to provide an incentive for students to read it and break some of the monotony, and (5) students were periodically asked “what is going well and what can be improved upon” as part of their lab hand-in to gather real-time feedback so that we could make adjustments, if needed.

1.3 | Research questions

With the mid-semester pivot to an online format, we were concerned about the efficacy of our low-tech approach in supporting student access to the course material and assessments, as well as student preference and perception. Specifically, we wondered:

1. Would the low-tech delivery of the lecture, lab, and recitation material be well received by students and effective in supporting their learning?
2. Given students had access to both low- and high-tech options for the lab video instruction and lab quizzing, which format would students use and prefer?
3. Would the practice exam and effort-based release of an answer key be an effective substitute for review sessions (i.e., would the students find it helpful)?
4. Overall, how would students view our online approach?

Although we did not include measurement of student performance or learning as a research question, we did monitor student performance (i.e., lecture participation, lab completion, recitation exercises and quizzes, and exams) after the transition to remote learning to make sure that students were not falling behind and were able to access the course material.
2 | MATERIALS AND METHODS

2.1 | Survey

In Spring 2020, prior to the final exam week, students were invited to complete a voluntary survey using Qualtrics (Qualtrics XM; www.qualtrics.com) focused on student preferences and perception related to the online delivery of the lectures, labs, and recitations. Students were also asked about internet access availability, exam preparation, and comparisons between the online and in-person format. The survey consisted of questions using a combination of five-point Likert-scale ratings, multiple choice, and open-ended responses. Two extra credit points (worth ∼0.4% of their total grade) were awarded for either completion of the survey or completing an alternative short course-related assignment, equivalent in time and effort to the survey. A list of questions asked in the student survey is included in the Supporting Material Table S1.

Student responses from both classes, Soil Science and Forest Soils, were aggregated and reported as a percentage (%) where appropriate. Means for Likert scale responses were calculated on a scale of one (strongly disagree) to five (strongly agree). Open-ended questions were used to help explain student responses to the related questions.

2.2 | Analysis

Comparisons of the responses to the survey questions were made against gender identity, course (Soil Science or Forest Soils), classification (freshman, sophomore, junior, and senior), and recitation leader. The Likert scale responses were aggregated into strongly agree/agree, neither agree nor disagree, disagree/strongly disagree, and undecided using the unrounded values and then rounded after aggregation (thus there may be a slight discrepancy with the rounded numbers reported in Supporting Material Table S1). Classification was aggregated into freshman, sophomore, and junior/senior (due to small cell counts). Chi-square tests of association were used except in cases where cell counts were too low to ensure accuracy of the tests; in such cases either a Fisher’s Exact Test for 2 x 2 tables or tests of concordance were used. All tests utilized Minitab version 19 (Minitab, Inc.). Associated tests and results for each comparison are included in Supporting Material Table S2.

3 | RESULTS

3.1 | Demographics

In total, 179 students (95% response) responded to the voluntary survey. Of those that responded, 66% were from the Soil Science course and 34% were from Forest Soils. In terms of gender identity, 47% self-identified as female, 35% male, 2% non-binary, and 16% preferred not to answer. Sophomores were most heavily represented at 49%, followed by juniors (16%), freshmen (13%), and seniors (6%), with 17% preferring not to answer. College representation was 76% College of Agriculture, 5% College of Engineering, 2% College of Science, with 17% preferring not to say. The top majors represented were Wildlife (21%), followed by Agricultural Systems Management (7%), Natural Resources and Environmental Sciences (7%), Agronomy (7%), Agribusiness (6%), Environmental and Ecological Engineering (5%), Forestry (5%), and Horticulture (5%).

3.2 | Statistical comparisons

The comparisons of the responses to the survey questions vs. gender identity, course, classification, and recitation leader showed no apparent differences. In the few (six) cases where statistical differences were identified, the statistical result was either not practically different, was due to differences in “undecided” responses, or both. For those cases where statistical differences were identified, an explanation of the differences detected by the tests are addressed below. Results for each comparison are included in Supporting Material Table S2.

3.3 | Survey responses

For each of the following, aggregate responses (%) are shown in Figure 2. Note that while Likert scale responses were aggregated into strongly agree/agree, neither agree nor disagree, disagree/strongly disagree, and undecided using the unrounded values and then rounded after aggregation (thus there may be a slight discrepancy with the rounded numbers reported in Supporting Material Table S1). Classification was aggregated into freshman, sophomore, and junior/senior (due to small cell counts). Chi-square tests of association were used except in cases where cell counts were too low to ensure accuracy of the tests; in such cases either a Fisher’s Exact Test for 2 x 2 tables or tests of concordance were used. All tests utilized Minitab version 19 (Minitab, Inc.). Associated tests and results for each comparison are included in Supporting Material Table S2.

3.3.1 | Lecture

With a mean response of 4.32, most respondents (87%) found the low-tech (lecture slides + transcript) delivery format to be effective in supporting their learning of the material. While 39% would have preferred the lectures to be delivered via video, 30% preferred the low-tech format with a mean response of 3.2 (Figure 2a). Comparisons of the responses to both questions vs. course, classification, and recitation leader showed no apparent differences. In the few (six) cases where statistical differences were identified, the statistical result was either not practically different, was due to differences in “undecided” responses, or both. For those cases where statistical differences were identified, an explanation of the differences detected by the tests are addressed below. Results for each comparison are included in Supporting Material Table S2.
leader showed no apparent differences. Comparisons to the responses did show a slight statistical difference in usefulness and preferences associated with the low-tech format across gender identity ($p < .01$ and $p < .02$, respectively), although this was primarily due to more undecided responses from males (Supporting Material Table S2).

### 3.3.2 Lab

Despite 89% of the respondents reporting at the end of the semester to have high speed internet access (Supporting Material Table S1), only 55% of the students continued to use the high-tech video-delivery as their primary lab delivery.
format. The remaining 30% of the respondents primarily used the low-tech delivery (lab video slides + transcript) and 15% used both formats equally. Overall, of those that used both lab delivery formats (n = 108), 52% preferred the video (high-tech delivery), 31% preferred the low-tech solution, with the remainder showed no strong preference either way (Figure 2b).

Although all lab materials (photos of benchwork, lab packets, and supplemental readings) were sent out via email each week, a majority (59%) still accessed the materials via the LMS, with 18% using the emailed materials exclusively, and the remaining 23% using both depending on the week (Figure 2c).

A majority (66%) of respondents found the substitution of pictures in place of the in-person interaction with the lab bench materials to be effective in supporting their learning with a mean response of 3.58 (Figure 2d). Students reported that the LMS delivery of the weekly lab hand-in was enjoyable (61%, mean response 3.6) and effective in supporting their learning (83%, mean response 4.01) (Figure 2e). Interestingly, students preferred the LMS version of the hand-in (52%) to the paper hand-in used in the in-person course (with a mean response of 3.27 (Figure 2f).

Given all of this, 74% of the respondents reported that the online lab was effective in supporting their learning, with 9% disagreeing with that sentiment (Figure 2g). The mean response was 3.82.

Comparisons to the responses concerning both questions about the lab hand-in did show a slight statistical difference in respect to recitation leaders, with more respondents from one recitation leader undecided on whether they enjoyed the LMS delivery of the recitation exercises (Supporting Material Table S2). Comparisons of the responses of all other recitation-related questions vs. gender identity, course, classification, and recitation leader showed no apparent differences.

3.3.4  Exam preparation

The low-tech exam preparation replacement (practice exam + effort-based release of the answer key) was viewed positively by a strong majority of respondents with 90% completing the upload of the PDF practice exam. Of these (n = 161), 92% reported that this exercise benefited their performance on the exam (Figure 2i) with a mean response of 4.56.

3.3.5  Overall

In agreement with our preliminary survey asking about internet access in March 2020 that showed 10% lacking reliable internet access off campus, 11% of the respondents reported they still did not have reliable internet access capable of streaming video after the transition to remote learning (Supporting Material Table S1). Slightly more male students than female students identified as having limited internet (p < .02) (Supporting Material Table S1 and S2).

When asked whether the online instruction was as effective as the in-person instruction prior to the COVID-19 shutdown, a plurality (48%) reported it was as effective while 34% reported in-person instruction was more effective (mean response was 3.2). When asked whether they preferred the online delivery of the course to in-person instruction, 63% disagreed, 20% were undecided, and only 17% agreed (Figure 2k) with a mean response of 2.34. Nevertheless, 69% of the respondents found the online delivery of this course to be more effective than their other courses with a mean response of 3.89 (Figure 2l).
Although we did not specifically seek to measure student performance or learning as a research question, overall student performance (i.e., completion of course deliverables) generally remained constant after the transition to online delivery. A comparison of the average hourly exam grades found less than a 2% difference between Spring 2020 and the previous semester, Fall 2019. Average grades earned on Exam 3, which was given online in Spring 2020, were within 1% of Fall 2019. A comparison of the final course grades earned between Fall 2019 and Spring 2020 also showed no noticeable differences in the final course grade distributions.

4 | DISCUSSION

Pivoting to an online format mid-semester in Spring 2020 was a challenge that threw students and instructors alike into uncharted territory. Our choice to offer a low-tech format was largely centered around concerns that a significant number of our students (~10% based on our March 2020 survey conducted prior to the switch to online instruction) would not have access to stable internet capable of streaming video formats of lectures, labs, and recitations or access to a computer (~10%) capable of using advanced features in the LMS. In general, our approach was viewed positively by students, as discussed below.

4.1 | How did students view the low-tech delivery of lecture material?

Overall, the low-tech (PDF + transcript) delivery of the lecture material was well received by most students, although respondents were split as to whether they would have preferred video-delivery of the lectures if given the option. Student comments (Supporting Material Table S3a), suggests that this preference was largely dependent on learning preferences and time management. For example, one student stated, “I think it was helpful having the transcript and the PowerPoint instead of a video because I don’t have the best internet and it would have taken longer and been frustrating to stream videos.” For this particular student, it was quicker to read the transcript than try to download and watch a 50-minute lecture.

How students perceived their learning preference(s) also seemed to influence their ability to focus and learn when material was presented through PDF + transcript, audio and/or video content. Some students noted it was easier for them to pay attention to audio and video, while others said the PDF + transcript was easier to follow and review. For example, one student stated, “I preferred the videos because it was easier to learn from, but I understand that people without internet would need the transcript.” While another student stated that they “actually did like the lecture being in a PowerPoint format with transcript added. It was different than my other classes and I sort of liked that it wasn’t in video format.”

One student also highlighted the need to provide transcripts or captioning of all material regardless of format, to ensure accessibility to those that may be hearing impaired, stating “It all worked very well for me specifically as a hard of hearing student. The transcripts really helped me get information that otherwise I would have missed during in person lectures.” Transcripts or captioning of materials also has benefits to a broader audience including those with different learning preferences or those where English may not be their first language (Dallas et al., 2016; Udo & Fels, 2010). Some suggestions by students included (1) offering a high-tech option (video) as an addition to the low-tech delivery of the lecture or (2) offering at an audio track to supplement the lecture (e.g., voice-over-PowerPoint).

4.2 | How was the flexible (low- and high-tech) online delivery of lab material received?

The lab material was offered in both low- and high-tech formats. Interestingly, despite only 11% reporting internet limitations at the end of the semester, almost half of the respondents used the low-tech format (30%) or a combination of both (15%). Format preference similarly tracked with respondent usage. This is consistent with the comments referenced above concerning preferences for either video or transcript delivery of course material. How students accessed the material (LMS vs email) was split (59% using the LMS with the remaining using email or a combination), with some describing email delivery as useful, while others felt it was unnecessary or overwhelming. This highlights the need for email communication with students and attachments to be organized and purposeful (as reviewed by Crawford-Ferre & Wiest, 2015).

Digital delivery of the labs (i.e., photographs of benchwork, the electronic format of the lab packet, and LMS delivery of the weekly hand-in) was generally well received with a strong majority (74%) reporting that the overall lab format was effective in supporting their learning. The fact that the lab was already flipped seemed to help students with the transition to the online format. Recommendations from respondents (Supporting Material Table S3b) include: making sure all photos and scans are high quality/clear and well organized. Both are areas to improve upon in the future. Additionally, some students expressed the expectation that online labs should be shorter (e.g., less material) than in-person formats. While we do not advocate teaching less material, exploring if there are better or streamlined ways to deliver the same information would be worthwhile. While the immediate feedback offered by the LMS on the lab hand-ins was positively received, students noted that it was not a substitute for in-person interaction.
in the lab. While studies have shown that online and in-person learning outcomes are actually similar, students may perceive that they have learned less in online courses, especially if they have had limited previous experience with online education (Platt et al., 2014). Students did note that holding at least some virtual office hours during lab or moderating an online forum (Piazza or the LMS bulletin board) might help provide students with real-time help (as opposed to having to email the instructor or relying on “hints” via the LMS). Studies have shown these are both effective supplements to online instruction (as reviewed by Crawford-Ferre & Wiest, 2015). It is important to note, however, that while respondents indicated in their comments that elements of the online delivery were effective, for many it was not preferred over the in-person lab experience.

### 4.3 How was the low-tech delivery of recitation received?

With an approximate 16:1 ratio of students-to-instructor in each recitation section, students are typically provided with the opportunity to revisit the week’s material in a small, instructor and peer supported environment. Instructors were nervous about how the transition to an online format would resonate with the students. Nevertheless, a strong majority (76%) found the low-tech format of the online recitation to be effective in supporting their learning. In particular, students felt that the LMS-delivered practice exercises were enjoyable (61%) and effective (82%). While only 56% of the students found the quizzes to be enjoyable, most students (78%) felt that the online quizzes were effective in testing their understanding of the weekly material with a plurality preferring the format to in-person quizzes. Although respondents (Supporting Material Table S3c) recognized the value and efficacy of the online recitation approach used, many said that it was not a replacement for the in-person recitation experience with some reporting that they missed the peer interaction and in-person review nature/atmosphere. Studies have shown online course generally offer less opportunities for instructor and peer interaction (Platt et al., 2014). Having short videos, recitation-specific chatrooms, or personalized communication (transcripts) from the individual recitation leaders to their classes may provide a way to keep some of that connectivity from being lost (as reviewed by Crawford-Ferre & Wiest, 2015).

### 4.4 What were the overall impressions?

Instructors were hesitant to release the keys to the practice exams given evidence that students may study the key rather than focusing on their understanding of the material. Thus, we required students to attempt the practice exam to receive access to the answer key. In the end, 90% of the students completed an attempt and uploaded a PDF of their practice exam. Students reported this method was effective in helping them prepare for the exam. As mentioned earlier, we opted to randomize the release of the exam questions, delivered one at a time, and disabled backtracking to minimize potential for cheating. We felt this was a better strategy than implementing online proctoring given that our pre-transition survey found that ~10% of the students lacked access to a computer capable of using these advanced applications of the LMS or highspeed internet access that would have allowed students to take the exams with their cameras turned on. However, a few respondents (Supporting Material Tables S3c and S3d) noted that this disrupted their usual in-person quiz/test-taking strategy which allowed them to skip around and come back to questions they struggled on later. To account for this, we allotted for three-times the regular amount of time for all assessments hoping this would allow them to take more time answering questions without feeling rushed and to account for environmental disruptions and technology issues. However, in the future, randomizing numbers in calculation problems and/or from pulling from question banks of similar questions, may provide an alternative format, while still allotting additional time in case technical issues or exam questions arise. Karanman (2011) and Fluck et al. (2009) have shown this to be an effective strategy in online assessment. Several respondents also noted the online assessment reduced their motivation to learn the material since they could just look it up when needed. Reworking problems to make them more concept-driven while providing more opportunities to apply what they learned in lab and recitation in the assessments could help increase student motivation (Bull & McKenna, 2004).

Despite strong majorities of respondents noting that our low-tech online delivery of lecture, lab, and recitation materials was effective in their learning, only a plurality (48%) perceived the online approach to be as effective as in-person instruction. This is not surprising given that student experiences in online and hybridized courses have largely been tied to individual learning preferences, traits/ perceptions, and previous experience in taking online courses (Horspool & Yang, 2010; Mansour & Mupinga, 2007; Platt et al., 2014). It is also important to remember that students did not choose to enroll in an online course, but out of necessity were required to transition to a new format mid-semester with little notice. Studies have shown the transition to remote instruction during the COVID-19 pandemic has resulted in increased distractions, anxiety, and stress, and a decrease in student motivation (Gillis & Krull, 2020). It is not surprising then, that only 17% of our respondents preferred the online instruction to the in-person course. We were bolstered, however, that 69% of the students found our online delivery to be more effective than their other courses, specifically referencing our
flexibility, understanding, and options for remote delivery of the latter half of the course. Students (Supporting Material Table S3d) identified key strengths of our approach to include: slides + transcript availability, clear organization and communication of deliverables, and yes... humor. Studies have shown that humor can be extremely effective in in-person and online education because of its potential to humanize, engage, reduce anxiety, and connect with students (Hackathorn et al., 2011; Nasiri & Mafakheri, 2015; Torok et al., 2004).

5 | CONCLUSIONS AND FUTURE WORK

We designed the online delivery of our course with the goal of making the material and experience accessible to all students, regardless of their high-speed internet availability or technology limitations. In this process, we learned that while most classes adopted a high-tech approach (Video, Zoom/WebEx), providing a low-tech delivery of the lecture, lab, and recitation material can be well received by, and effective in educating, students. Although not part of our initial research questions, comparisons between exam averages and course grade distributions showed no discernable difference between Spring 2020 and Fall 2019; however, future work specifically measuring and comparing student learning and performance beyond these metrics would provide evidence on the relative effectiveness of the low tech and high-tech approaches. Likewise, while students noted that the effort-based release of exam answer keys was helpful in their exam preparation, more studies are also needed to identify whether this approach is truly effective (perception vs performance), especially compared to in-person review sessions.

In reviewing student feedback, students noted the importance of being flexible and providing options to students, effectively providing students with some autonomy in their learning (Bonem et al., 2019; Ryan & Deci, 2017). When we refer to autonomy, it does not mean students have control over every aspect of the course, but rather that students are provided choices within the course structure (Reeve, 2009). In our case, we provided students with a choice on how they could engage with the lab material presented, such as watching lecture videos or choosing to review the lab PDF slides with transcripts, and larger windows to complete all assessments, increasing flexibility. Providing students with autonomy provides them with a feeling of volition and ownership over their learning and can even help with more internalized motivation in a course (Reeve, 2009). Using the pandemic as an example, if a lab course had the option to conduct a lab online or virtually, a student that is unable to attend an in-person lab while quarantined would be able to engage in a virtual lab (low or high tech) and have the ability to complete their lab assignments and not fall behind – something to consider as we move towards in-person courses again. While this is generally a good practice regardless of whether a class is taught in-person or remote, it is especially important during an unplanned event, such as a pandemic as it provides some level of choice in a time where it feels like students might have no control in any aspects of their life, not just their academic experience.

We also found it interesting that given the choice between video and low-tech alternatives (slide + transcripts), students will gravitate towards their learning preference, even if they have access to broadband internet. In a time where TikTok, YouTube, and Instagram are dominant players, not everyone prefers or learns best through video delivery. Nevertheless, our students clearly had preferences suggesting that providing both methods would likely be the most effective solution to address all learning preferences. This would reduce the barriers to students who may lack high-speed internet or home computers, maintain accessibility for diverse student populations through captioning and transcripts, while providing support to those students that prefer audio or video delivery of the course material. Such a comprehensive approach (low + high tech), however, may create an additional burden on the instructors since one would have to generate additional materials; however, repurposing slides and transcripts from captioned video may be one a way to minimize some of the additional work. While we recognize that providing both solutions could also potentially create some unfairness to those who lack the ability to use the high-tech options, we found that students, regardless of their situation, appreciated the availability of the low-tech solution. Ultimately, being aware of the barriers that students face in specific classes (e.g., from rural areas that might have limited broadband or access to technology and learning preferences) should help drive this decision – during and beyond the COVID-19 pandemic.

Finally, although online instruction is generally associated with reduced connections between the instructor and student (Platt et al., 2014), being understanding and empathetic of student situations and demonstrating that you care about their learning can increase connections between the instructor and student. Regardless of the format chosen, students need clear communication, organized delivery of high-quality material, and yes... the occasional joke. In the words of one of our students, keep all of this in mind and “it’s Gucci.”

ACKNOWLEDGMENTS

A special thanks to our graduate teaching assistants (Alyssa Besser, Shams Rahmani, Parker Thomas, Daniel Welage, and Adam Wehrman); Connie Foster; Nastasha Johnson, our instructional design team (Debra Dunlap Runshe; Vincent Hornbach; Allan Celik; and Mark Fisher); our faculty lab instructors (Dr. Eileen Klavidko, Dr. Bill McFee, Dr. Darrell Shulze, Dr. Shalamar Armstrong, Dr. Laura Bowling, Dr. Cliff Johnston, Dr. Linda Lee, Dr. Ron Turco, Dr. John Graveel, Dr. Bob Nelson, and Dr. Jim Camberato); and Dr. Steven Landry.
M. L. Mashtare also wishes to thank his young daughter, Lee, who has been mostly patient and understanding during the pandemic making completion of this work possible. The use of survey data was reviewed by the Penn State University Institutional Review Board and was determined not to constitute human research because it utilized previously collected (historical) anonymous data.

**AUTHOR CONTRIBUTIONS**

Michael L. Mashtare: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Visualization; Writing-original draft; Writing-review & editing. Charlotte I. Lee: Data curation; Validation; Writing-review & editing. Sherry S. Fulk-Bringman: Conceptualization; Investigation; Writing-review & editing. Erica A. Lott: Validation; Writing-original draft; Writing-review & editing.

**CONFLICT OF INTEREST**

The authors declare no conflict of interest.

**ORCID**

Michael L. Mashtare https://orcid.org/0000-0001-8987-5863  
Charlotte I. Lee https://orcid.org/0000-0003-4859-8999  
Sherry S. Fulk-Bringman https://orcid.org/0000-0002-3045-1510  
Erica A. Lott https://orcid.org/0000-0001-8865-3986

**REFERENCES**

Bonem, E. M., Fedesco, H. N., & Zissimopoulos, A. N. (2019). What you do is less important than how you do it: The effects of learning environment on student outcomes. *Learning Environments Research*, 1–18.

Bull, J., & McKenna, C. (2004). *Blueprint for computer-assisted assessment*. London: RoutledgeFalmer. Burgoon J, Stoner M, Bonito J, D Crawford-Ferre, H. G., & Wiest, L. R. (2015). Effective online instruction in higher education. *The Quarterly Review of Distance Education*, 13, 11–14.

Dallas, B., McCarthy, A., & Long, G. (2016). Examining the educational benefits of and attitudes toward closed captioning among undergraduate students. *Journal of the Scholarship of Teaching and Learning*, 16, 56–65. https://doi.org/10.14434/jostel.v16i2.19267

Fask, A., Englander, F., & Wang, Z. (2014). Do online exams facilitate cheating? An experiment designed to separate possible cheating from the effect of the online test taking environment. *Journal of Academic Ethics*, 12, 101–112. https://doi.org/10.1007/s10805-014-9207-1

Fluck, A., Pullen, D., & Harper, C. (2009). Case study of a computer based examination system. *Australasian Journal of Educational Technology*, 25, 509–523. https://doi.org/10.14742/ajet.1126

Gillis, A., & Krull, L. M. (2020). COVID-19 remote learning transition in spring 2020: Class structures, student perceptions, and inequality in college courses. *Teaching Sociology*, 48, 283–299. https://doi.org/10.1177/0092025520954263

Hackathorn, J., Garczynski, A. M., Blankmeyer, K., Tennial, R. D., & Solomon, E. D. (2011). All kidding aside: Humor increases learning at knowledge and comprehension levels. *Journal of The Scholarship of Teaching and Learning*, 11, 116–123.

Hollister, K. K., & Berenson, M. L. (2009). Proctored versus unproctored online exams: Studying the impact of exam environment on student performance. *Decision Sciences Journal of Innovative Education*, 7, 271–294. https://doi.org/10.1111/j.1540-4699.2008.00220.x

Horspool, A., & Yang, S. S. (2010). A comparison of university student perceptions and success learning music online and face-to-face. *MERLOT Journal of Online Learning and Teaching*, 6, 15–29.

Karaman, S. (2011). Examining the effects of flexible online exams on students’ engagement in e-learning. *Educational Research and Reviews*, 6, 359–364.

Khan, S., & Khan, R. A. (2019). Online assessments: Exploring perspectives of university students. *Education and Information Technologies*, 24, 661–677. https://doi.org/10.1007/s10639-018-9797-0

Lai, J., Widmar, N. O., & Bir, C. (2020). Eliciting consumer willingness to pay for home internet service: Closing the digital divide in the state of Indiana. *Applied Economic Perspectives and Policy*, 42, 263–282. https://doi.org/10.1002/aepp.13000

Mansour, B. E., & Mupinga, D. M. (2007). Student’s positive and negative experiences in hybrid and online classes. *College Student Journal*, 41, 242–248.

Nasiri, F., & Mafakheri, F. (2015). Higher education lecturing and humor: From perspectives to strategies. *Higher Education Studies*, 5, 26–31. https://doi.org/10.5539/hes.v5n5p26

Platt, C. A., Raile, A. N. W., & Yu, N. (2014). Virtually the same? Student perceptions of the equivalence of online classes to face-to-face classes. *MERLOT Journal of Online Learning and Teaching*, 10, 489–503.

Reeve, J. (2009). Why teachers adopt a controlling motivating style toward students and how they can become more autonomy supportive. *Educational Psychology*, 44, 159–175. https://doi.org/10.1080/00461520903028990

Ryan, R. M., & Deci, E. L. (2017). *Self-determination theory: Basic psychological needs in motivation, development and wellness*. New York: The Guilford Press.

Torok, S. E., Mcmorris, R. F., & Lin, W-C. (2004). Is humor an appreciated teaching tool? Perceptions of professors’ teaching styles and use of humor. *College Teaching*, 52, 14–20. https://doi.org/10.3200/CTCH.52.1.14-20

Udo, J. P., & Fels, D. I. (2010). The rogue poster-children of universal design: Closed captioning and audio description. *Journal of Engineering Design*, 21, 207–221. https://doi.org/10.1080/09544820903310691

**SUPPORTING INFORMATION**

Additional supporting information may be found online in the Supporting Information section at the end of the article.

*How to cite this article:* Mashtare ML, CI, Fulk-Bringman SS, Lott EA. When low and high tech solutions converge: Adapting to teaching soils during the COVID-19 pandemic. *Nat Sci Educ.*, 2021;50:e20057. https://doi.org/10.1002/nse2.20057