Flipped teaching eased the transition from face-to-face teaching to online instruction during the COVID-19 pandemic

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Abstract

Due to the COVID-19 pandemic, Rice University canceled classes for the week of March 9–13, 2020 and shifted all instruction to online only following spring break. For the second half of the semester, animal physiology was taught exclusively over Zoom. Here we describe how a flipped teaching format that was used before the pandemic eased the transition from face-to-face teaching to online instruction. The preclass preparation resources and the active learning materials that were already in place for flipped teaching were helpful in the transition to solely online teaching. Therefore, the focus during the transition was to reconfigure active learning and examinations from the face-to-face format to the online platform. Instead of small group discussions in the classroom, teams interacted in Zoom Breakout Rooms. Rather than taking exams in-person during scheduled class time, students submitted exams online. Additionally, students prerecorded their project presentations instead of presenting them “live” during the last week of classes. Overall, students felt that the class smoothly transitioned to a remote only format. These and other changes to the instructional methods will be implemented during the Spring 2021 semester when the course is taught fully online.

flipped teaching; online instruction; student-centered teaching; teamwork

INTRODUCTION

Flipped teaching is a student-centered instructional format that shifts lectures out of the classroom, freeing up class time for active learning. This teaching method is designed around engaging students deeply with content and providing immediate feedback (1). Flipped teaching not only allows the active participation of students but also introduces concepts in a recurring manner with access to help and opportunities to work with peers (2). While flipped teaching increases student preparedness (3–5), it also allows instructors to engage students in higher levels of critical thinking as defined by Bloom’s taxonomy (6), such as application, analysis, and synthesis (7, 8) and helps develop skills such as problem-solving, collaboration, and self-direction (9, 10). Common characteristics of flipped teaching are intentional partial transfer of information delivery to outside of the classroom to maximize face-to-face interaction in the classroom; transformation of teachers to facilitators rather than dispensers of facts, and students to active learners rather than receptacles for information; and availability of content that students can use for easy and immediate access to any topic and the use of class time to expand on higher-order thinking skills, collaboration, and enrichment instead of to deliver standard lectures (11, 12).

Flipped teaching is particularly beneficial in STEM teaching since it provides more in-depth learning of content (13). The COVID-19 pandemic presented a challenge in the continuation of flipped teaching in its original form due to the necessity of transitioning to online teaching. To continue to aid in student learning and engagement, a revised flipped teaching method was developed for remote instruction that consistently maintained a synchronous component in order to preserve the collaborative, active learning necessary for flipped instruction. A combination of synchronous and asynchronous online components allowed the instructors to maintain a level of student engagement similar to that of the face-to-face setting.

OUR ANIMAL PHYSIOLOGY COURSE INCORPORATES A FLIPPED TEACHING FORMAT

Animal Physiology is a backward-designed, student-centered course that uses an integrated approach to learning animal physiology, incorporates multiple evidence-based teaching strategies, and emphasizes primary literature (14). Students investigate the comparative animal physiology of vertebrates, including strategies that animals use to meet their energy needs, take up and transport oxygen, and maintain hydration and salt balance, with a special emphasis on how animals have adapted to extreme environments. Teamwork is emphasized throughout the course, with students working in groups both inside and outside of class. The teams are quite diverse with students at all levels encompassing a variety of majors. With a year of introductory biology for majors as the sole prerequisite, this
intermediate-level elective course is accessible to undergraduates at all levels and to both biosciences majors and nonmajors, including some majors outside of natural sciences. A typical class size is 15–20 students with 4–5 students per team; 18 students enrolled in this course in Spring 2020. Instructor-provided study materials included chapter guides for the textbook, reading guides for research papers, worksheets and homework sets, online quizzes and assignments, and links to supplemental videos and websites. Students accessed resources and assignments through the institutional learning management system (Canvas LMS). Each team had an “activity box” with supplies such as index cards, markers, scissors, and tape to support in-class group work. All protocols were approved by the Institutional Review Board of Rice University (Protocol FY2017-294).

The course, which was first offered in 2014, was intentionally designed with a flipped teaching (FT) format, where students are assigned readings from the textbook and articles from the primary literature outside of class and class time is spent discussing the material and applying that information to explore physiological mechanisms. Instead of lecturing, class time is focused on interactive learning through group work; for example, group work includes in-class activities, worksheets, homework problems, class discussions about textbook readings and research articles, and question sets for a semester long group project. Retrieval practice (15) occurs primarily through mini-exams, which are given every other week and consist of several short answer questions (see below), and Minute Questions (MQ), which are short quizzes given at the beginning of class. MQs are a retrieval exercise (RE) that focus on a key concept or theme that was covered in the assigned reading for that particular class. In the previous year, FT was combined with RE (3, 16) by introducing online quizzes on each assigned textbook reading and asking MQs each class meeting (17). For the Spring 2020 semester, in addition to reading quizzes for each textbook reading, students answered the background questions from the reading guide in an online quiz (FT) and were asked MQs about the research paper at the beginning of class (RE).

Table 1. Comparison of course structure in face-to-face teaching (pre-COVID) and online instruction (during COVID)

| Activity                        | Face-to-Face                                      | Online                                      |
|---------------------------------|--------------------------------------------------|---------------------------------------------|
| Class preparation               | Readings, videos, quizzes                        | Readings, videos, quizzes                   |
| Discussions                     | In-class                                         | Zoom                                        |
| Group work                      | SCAL@R classroom                                 | Zoom Breakout Rooms                         |
| Mini-exams                      | In-class (50 min)                                | Canvas LMS (60 min/灵活窗口)                |
| Group exams                     | Canvas LMS (untimed)                             | Canvas LMS (untimed)                        |
| Final exam                      | In-class (3 h)                                   | Canvas LMS (3 h 45 min/灵活窗口)             |
| Research article exams          | Canvas LMS (untimed)                             | Canvas LMS (untimed)                        |
| Project presentations           | Live/in-class                                    | Prerecorded/watch party                     |

SCAL@R, Student-Centered Active Learning at Rice; LMS, learning management system.

A FLIPPED TEACHING FORMAT FACILITATED THE TRANSITION TO ONLINE INSTRUCTION

During the first 8 wk of the semester (pre-COVID), students regularly attended class 2 days a week for 75 min each session and actively participated in activities and class discussions focused on the textbook material and the research articles. As the COVID-19 pandemic accelerated last spring, Rice University, Houston, TX, canceled classes for the week of March 9–13, 2020 and shifted all classes to a remote learning format after spring break. For the remaining seven weeks of the semester, students attended virtual class synchronously for the same days and times as pre-COVID. We had essentially a 2-wk window to adapt a face-to-face course to an online format. Table 1 compares key instructional activities in face-to-face (pre-COVID) teaching to online instruction (post-COVID). Because this class was already flipped before the pandemic, student preparation for class did not change once instruction moved to online. Although we do not “lecture” in this course, we did record class meetings in Zoom and posted them in Canvas. Class attendance was mandatory except for one student in Hawaii who participated asynchronously; this student watched the recordings when it was class time in Hawaii and met with group members in their own Zoom meeting at least once during the week. MQs, which were administered through Canvas at the beginning of each class, served as a record of attendance as students must attend class to earn credit. Instead of small group discussions in a SCAL@R (“Student-Centered Active Learning at Rice”; https://registrar.rice.edu/facstaff/student-centered-active-learning-at-rice) classroom (18–20), student teams interacted with each other in Zoom Breakout Rooms. Consequently, class discussions continued with only minor modifications to content and structure. Similar to the first half of the semester, engagement was assessed during class by student participation in discussions and activities. As students had been working with their teams since the beginning of the semester and classes were built around discussions rather than traditional didactic lectures, the move to Zoom class went relatively smoothly. The biggest changes we made were in two major areas: 1) exam format; and 2) fictional animal project (21).

Exams, which consisted of mini-exams, group exams, research article exams, and a final exam, contributed to 70% of the overall course grade. The research article exams were submitted online in Canvas; although the format for these exams did not change when we shifted to online instruction, we did drop the third exam. Approximately every other week, students were given a mini-exam with four to five short answer questions that target higher levels of Bloom’s taxonomy. Throughout the semester students practiced answering similar types of questions while preparing for class (online quizzes), during class (MQs, class discussions), and after class (homework, exam preparation); they worked with open-ended questions for each research article discussion,
and we assigned study questions at the end of each textbook chapter that are at higher Bloom’s levels and are similar to the types of questions we ask on exams; in fact, we used some of the study questions from the textbook on the exams. These mini-exams were “closed resources” for both in-person and online exams. During the first half of the semester (pre-COVID), mini-exams were administered in-class; students had 50 min to complete the exam, and answers were hand-written. When classes moved online, students took the mini-exams using Canvas LMS. Once students started the assessment in Canvas, they had 60 min to complete each exam; instead of giving the exam during a scheduled class meeting, we created a “window” of 7–10 days where they could choose when to take the exam. The cancellation of classes for the entire week before the transition to online instruction resulted in exams and assignments being due in many classes around the same time. This flexibility for taking the exams was essential to support the students and minimize additional anxiety and stress associated with the shift to online instruction. The students appreciated having options:
• “The take home exams were great so we could balance study loads”; and
• “Recording lectures, exams to be completed at your leisure was a lifesaver.”

Similar to the mini-exams, the final exam, which consisted of 15 short answer questions, was also administered through Canvas. Following the recommendations of the Office of the Registrar and the Faculty Senate at Rice University, we opened up the window to take the exam on the last day of classes and closed it on the last day of finals; the students could choose any time during this 12-day window to take the exam. We also extended the time from the standard 3 h for an in-person final examination to 3.75 h, giving students additional time to compensate for the exam remotely and needing extra time to type their answers or upload drawings. Furthermore, we made the final exam “open resources,” allowing students to use their notes from class, the textbook, research articles, or other resources, including the internet. The students really appreciated being able to focus on “bigger picture” concepts and themes as they were studying for the final and not worry about memorizing lots of facts; based on their feedback and the quality of their answers on the final exam, we decided to make all mini-exams as well as the final exam “open resources” for the Spring 2021 semester. These exams, plus an untimed, online group exam for each unit, will contribute to just 25% of the overall course grade.

Exam scores for the 18 students in Spring 2020 were comparable between the first half, when classes and exams were conducted in-person, and the second half when classes were 100% remote and exams were conducted online. Mean scores (SD) on individual mini-exams 1–3, conducted in-person in the first half of the semester, were 80% (SD 11). Mean scores on mini-exams 4–6 and the final exam, all conducted online after the transition to online instruction, were 85% (SD 12). Differences in the level of difficulty of the content covered on individual exams complicated this comparison; thus between-year comparisons of individual performance may be more appropriate. Students in 2018 (n = 18) averaged 77% (SD 18) on the first three mini-exams and 80% (SD 14) on the last three mini-exams and the final. The four students in 2019 averaged 87% (SD 8) and 90% (SD 7) on the same sets of exams. These data were not normally distributed; in fact, the distribution in 2018 was bimodal, precluding further statistical analysis. There is no evidence to suggest that the switch to remote learning in March 2020 had a negative impact on individual performance on exams.

Yet another part of this course is a semester-long project of student teams creating a fictional animal (21). The project is scaffolded to help students develop their animal system by system. As a group, they submit multiple question sets as homework. Earlier in the semester, students were able to work on their animal during class time; however, after classes moved to online only, this type of group work was no longer effective as students could only talk one at a time and share a single screen in Zoom. The highlight of the project is the Fictional Animal Showcase, which is held during the last week of classes; each team gives a 15- to 20-min presentation about their animal and its physiology. Before Spring 2020, these presentations were “live” presentations during class. For Spring 2020, we gave the students the option of prerecording their presentation; we uploaded their presentation to Canvas LMS. We held “watch parties” where we watched each presentation video as a class followed by a “live” question and answer session for each team. Although the prerecording was optional, all five teams chose to “flip” their presentations by recording them in advance. During in-person classes, we instructors very much enjoyed watching student presentations about such clever and creative fictional animals; with recorded presentations we now have an archive of these student artefacts.

• “I would recommend possibly submitting the fictional animal presentation via video to be incorporated (in future semesters). I think that gave us more freedom to curate a better presentation.”
• “…having the option to record and present the recording of the animal showcase is a better choice for some people; I liked doing it that way since it relieved the stress of in-person presenting.”
• “…prerecorded presentation is also a good way to prevent internet issues and other technical issues.”

We would anticipate a greater impact of remote delivery on the quality of group work. In previous semesters, the best performing groups worked as a team on the group exams and fictional animal homework question sets. The worst performing groups were those who split up the work by giving responsibility for each question to a single individual. No such decline in quality was evident in the second half of 2020. Year-to-year comparison of the quality of group exam work is difficult because the format was changed from semester to semester. Average scores on group exam questions were 88% (SD 15), 82% (SD 21), and 87% (SD 15) in the first half of years 2018, 2019, and 2020, respectively, and 88% (SD 7), 78% (SD 12), and 90% (SD 10) in the second half of each respective year. For the Fictional Animal assignments, which did not change substantially over the 3 yr, average scores on the first assignment (first half of the course) were 92% (SD 6), 100%, and 99% (SD 2) for 2018, 2019, and 2020, respectively; in 2019 we had only one group and thus only one data point for the first half. In the second half, mean scores on the final three assignments were 98% (SD 3), 93% (SD 3), and 97% (SD 5) for the 3 yr.
In summary, the flipped teaching format not only helped students transition to online learning seamlessly but also saved the faculty from having to convert an entire course from in-person to remote. Having had the content in a virtual format (Canvas), there was no last-minute rush to prepare the material for the online teaching. There was no need to record any lectures or create new materials for online delivery. Instead, we were able to focus on refining class discussions for the Zoom format. We did not observe any differences in student performance on the exams or group work in-person versus online when comparing pre- and postremote instruction during the Spring 2020 semester or when comparing to face-to-face instruction in previous semesters.

### STUDENT ENGAGEMENT AND PARTICIPATION PERSISTED AFTER INSTRUCTION MOVED ONLINE

After the switch to online instruction, all but one of the students attended class online in a synchronous format; the one student who was unable to attend was in Hawaii. Unlike many of our colleagues at Rice, we did not see a decrease in class attendance after moving our class to a remote learning environment. We attribute the continued class attendance to the unique structure of our course: there were not recorded lectures for students to watch, and the recordings of our class sessions, which were available after each class, would not have been as useful of a learning tool without being present during class. In fact, the students commented on how much they missed the interactive components when we shifted to Zoom class. At the end of the semester, we administered an anonymous survey designed by the Rice Center for Teaching Excellence ([https://cte.rice.edu/blogarchive/2020/4/20/reflecting-on-our-remote-courses-during-the-covid-19-pandemic-what-has-the-rapid-transition-to-remote-teaching-taught-us](https://cte.rice.edu/blogarchive/2020/4/20/reflecting-on-our-remote-courses-during-the-covid-19-pandemic-what-has-the-rapid-transition-to-remote-teaching-taught-us)) to get feedback from students about the mid-semester transition to remote learning. Although only half of the students in the course completed the survey, they gave us valuable information about what worked well and what did not after we moved online. As shown in Table 2, most of the students who responded to the survey still felt connected to their classmates and maintained good communication with the course instructors. The students agreed that our expectations were clearly communicated and that they still had numerous opportunities to work with the course material. We found it particularly encouraging that most of the students successfully managed the workload.

Overall, students reported that the quality of the course learning environment was similar pre-COVID and during COVID (Table 3). Since many of the resources, materials, and assignments for the course were available to students through the Canvas LMS, the transition to online was much smoother. The students were used to preparing for class and completing group work outside of class and were quite adept at using Canvas to access resources and submit their work. A. M. Petzold made the following recommendations in a Letter to the Editor: "Using an asynchronous approach to teaching…with many ‘modes’ of teaching, including audio only, downloadable files, and/or a direct online presentation…are often recommended as a method of getting around many of the hurdles that technology can place in front of online learning" ([22]). Many of the strategies that we continued to use or introduced during the remote learning phase of this course encouraged engagement and promoted student learning.

### WHAT CHALLENGES DID WE FACE AS WE TRANSITIONED TO ONLINE INSTRUCTION?

While in general, the switch to online learning was successful, there were several aspects of the course that did not transition well to the remote learning context. Some class activities did not work as intended in an online format. According to the student survey, the biggest challenge was with in-class, hands-on activities. Previously, we designed an interactive activity to help students understand counter-current multiplication in the mammalian kidney: this activity is highly effective in the classroom as students physically “flow through” the loop of Henle. When we attempted to translate this activity online, the students had a difficult time visualizing how the activity was supposed to flow and were still confused even after we spent an entire class session going through the activity. Although the learning value of this activity was lost, the students appreciated our attempt to implement the activity online and provided feedback and suggestions on ways to improve the online version. To address this challenge, we are working with an undergraduate student who was in this course during COVID and an undergraduate student majoring in computer science to “flip” the countercurrent multiplication activity: we will pilot this new interactive, online game in Spring 2021.

Hands-on activities that required a whiteboard or the supplies in the team activity boxes were dropped as these could not be implemented effectively online. A strip sequence activity on different methods animals use to produce ATP that we did pre-COVID would not have translated to online as

### Table 2. Student responses from an end of semester transition to remote learning survey

|                              | Strongly Agree | Agree | Neither Agree nor Disagree | Disagree | Strongly Disagree |
|------------------------------|----------------|-------|----------------------------|----------|-------------------|
| I felt connected to other students in this course. | 1              | 5     | 2                          | 1        | 1                 |
| I had good communication with my course instructor(s). | 3              | 5     | 1                          | 0        | 0                 |
| There were lots of opportunities for me to engage with the course material. | 5              | 3     | 1                          | 0        | 0                 |
| The course expectations were clearly communicated. | 4              | 4     | 0                          | 0        | 0                 |
| I was able to successfully manage the remote course workload. | 2              | 5     | 1                          | 1        | 0                 |

Survey was from Spring 2020 and developed by the Rice Center for Teaching Excellence: 9/18 students (50%) completed the anonymous survey; results are number of respondents.
Interaction (23). In addition to these modified approaches, we are currently exploring the use of different online tools to compensate for the lack of face-to-face brainstorming sessions. We have found that students can collaborate in Google Docs for worksheets and maps, as everyone can write on the document at the same time. Students can also interact with each other in breakout rooms and facilitated their discussions. In general, they liked the small group setting and appreciated having more time in the breakout rooms as well as encouraging them to complete more of the group work outside of class. Preparing for the work they will do in class not only will save time but also will generate more engagement. Defining tasks and assigning roles to group members are other strategies we can try to focus on the discussions in breakout rooms.

### What Happens Next?

As we evolve from the “emergency remote learning environment” (24) that was created by the pandemic, we must continue to try new strategies for engaging students in the learning process. Unlike last spring when we had 8 wk of face-to-face learning before moving online, students will begin our course this year in the Zoom environment. Consequently, they will miss out on the live version of the team-building activities we previously did in the first few weeks of classes. Building a community will be much more challenging as we start with an online platform. Some new approaches we will try include 1) “Getting to know each other” in a discussion thread in Canvas; 2) creating a music playlist for the class as an icebreaker activity; 3) choosing an animal to represent their team and adding that to their Zoom name; and 4) mixing up the teams in some of the breakout sessions. Many of the strategies we have adapted to teach online will still be valuable when we return to face-to-face teaching.

In summary, the flexibility with teaching a flipped course greatly facilitated our efforts to quickly adapt the course structure and assignments to remote instruction during the second half of the Spring 2020 semester. Most students readily adjusted to this transition to online learning and achieved the course learning goals, with 15/18 students earning “As” and the other 3 students earning “Bs”; this grade distribution was comparable to previous semesters that were taught fully face-to-face. In the final reflection assignment for the Spring 2020
semester, one student nicely captured the experience of rapidly shifting from face-to-face to online learning:

“It was a shame that class got interrupted, but I thought that the move online went about as well as could be expected. The readings and discussions were still there, and Zoom allowed us to keep our groups. The groups did have less contact, as most things were worked out over group-me as opposed to in person. People in the class did seem less likely to raise their hands as well, but that may be partially because of the newness of Zoom school. Maybe a class that was online from the beginning would have better participation. What I think was really lost in the transition were the in-class activities. It is hard to directly transfer something that was meant to be done with physical objects into a virtual environment. There would have been different activities planned if this class was designed to be virtual. .”

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DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

B.B. analyzed data; B.B. drafted manuscript; B.B., D.R.C., and C.G. edited and revised manuscript; B.B., D.R.C., and C.G. approved final version of manuscript.

REFERENCES

1. Al-Samarraie H, Shamsuddin A, Alzahrani Al. A flipped classroom model in higher education: a review of the evidence across disciplines. Educ Tech Res Dev 68: 1017–1035, 2020. doi:10.1007/s11423-019-09718-8.
2. Gopalan C. Effect of flipped teaching on student performance and perceptions in an Introductory Physiology course. Adv Physiol Educ 43: 28–33, 2019. doi:10.1152/advan.00051.2018.
3. Gopalan C, Fentem A, Rever AL. The refinement of flipped teaching implementation to include retrieval practice. Adv Physiol Educ 44: 131–137, 2020. doi:10.1152/advan.00143.2019.
4. Gopalan C, Klann MC. The effect of flipped teaching combined with modified team-based learning on student performance in physiology. Adv Physiol Educ 41: 363–367, 2017. doi:10.1152/advan.00179.2016.
5. McLaughlin JE, Robt MT, Glatt DM, Gharkholonarehe N, Davidson CA, Griffin LM, Mumper RJ. The flipped classroom: a course redesign to foster learning and engagement in a health professions school. Acad Med 89: 236–243, 2014. doi:10.1097/ACM.0000000000000086.
6. Krathwohl DR. A revision of Bloom’s taxonomy: an overview. Theory Practice 41: 212–218, 2002. doi:10.1207/s15404216tp4104_2.
7. Gilboy MB, Heinerichs S, Pazzaglia G. Enhancing student engagement using the flipped classroom. J Nutr Educ Behav 47: 109–114, 2015. doi:10.1016/j.jneb.2014.08.008.
8. O’Flaherty J, Phillips C. The use of flipped classrooms in higher education: a scoping review. Internet High Educ 25: 85–95, 2015.
9. Bergmann J, Sams A. Flipped Learning: Gateway to Student Engagement. Washington, DC: International Society for Technology in Education, 2014.
10. McLean S, Attardi SM, Faden L, Goldszmidt M. Flipped classrooms and student learning: not just surface gains. Adv Physiol Educ 40: 47–55, 2016. doi:10.1152/advan.00098.2015.
11. Bradley B, Hock M, Brassere-Hock I, Ruggles M. So you want to flip your class: 9 guidelines to read first (Online). Kappa Delta Pi New Teacher Advocate: 16–17. https://www.kdp.org/ [2017].
12. Ortman L. Use four pillars to support your learning to F-L-I-P (Online). Kappa Delta Pi New Teacher Advocate: 14–15. https://www.kdp.org/ [2017].
13. Wibawa B, Kardipah S. The flipped-blended model for STEM education to improve students’ performances. IJET 7: 1006–1009, 2018. doi:10.14419/ijet.v7i2.29.14298.
14. Beason-Abmayr KB, Caprette DR. Animal Physiology from Scratch (Abstract ITL-4). APS Workshop Program and Abstracts Booklet: 2014 APS Workshop. Rockville, MD: APS Institute on Teaching and Learning, 2014.
15. Karpicke JD, Roediger HL. The critical importance of retrieval for learning. Science 319: 966–968, 2008. doi:10.1126/science.1152408.
16. Dobson J, Linderholm T, Perez J. Retrieval practice enhances the ability to evaluate complex physiology information. Med Educ 52: 513–525, 2018. doi:10.1111/medu.13503.
17. Beason-Abmayr B. Does implementation of flipped teaching combined with retrieval practice enhance student engagement in class discussions (Abstract)? FASEB J Exp Biol 33: 598.7, 2019.
18. Beason-Abmayr B, Caprette D, Correa AM, Eich E, Solomon S. Towards Student-Centered Active Learning at Rice (SCAL@R) (Online). AAAS Vision and Change in Biology Undergraduate Education: Chronicling Change, Inspiring the Future. https://live-visionandchange.pantheonсом/7s-Rice u University, 2013.
19. Beichner R. The SCALE-UP Project: A Student-Centered Active Learning Environment for Undergraduate Programs: An Invited White Paper for the National Academy of Sciences. Washington, DC: National Academy of Sciences, 2008.
20. McCaig A. SCAL@R shakes up traditional classroom instruction at Rice (Online). Rice News. http://news.rice.edu/2012/10/05/scalr-shakes-up-traditional-classroom-instruction-at-rice [October 2012 Oct 2].
21. Blatch S, Cliff W, Beason-Abmayr B, Balpin P. The fictional animal project: a tool for helping students integrate body systems. Adv Physiol Educ 41: 239–243m, 2017. doi:10.1152/advan.00159.2016.
22. Petzold AM. Letter to the Editor: Resources and recommendations for a quick transition to online instruction in physiology. Adv Physiol Educ 44: 217–219, 2020. doi:10.1152/advan.00049.2020.
23. Lima KR, das Neves BH, Ramires CC, dos Santos Soares M, Martini VA, Luiza Freitas Lopes LF, Mello-Carpes PB. Student assessment of online tools to foster engagement during the COVID-19 quarantine. Adv Physiol Educ 44: 679–683, 2020. doi:10.1152/advan.00131.2020.
24. Vollbrecht PJ, Porter-Stransky KA, Lackey-Cornelson WL. Lessons learned while creating an effective emergency remote learning environment for students during the COVID-19 pandemic. Adv Physiol Educ 44: 722–725, 2020. doi:10.1152/advan.00140.2020.