DOI: https://doi.org/10.1128/jmbe.v22i1.2573

JMBE Journal of Microbiology & Biology Education

Implementing CUREs with Cookbook-Style Laboratory Exercises in In-Person, Online, and Hybrid Formats†

Erika L. Doctor, Melissa Lehman, and Cassandra S. Korte*
College of Arts and Sciences, Lynn University, Boca Raton, FL 33431

Course-based undergraduate research experiences (CUREs) provide students with ample opportunity to engage in the scientific process and are increasingly replacing more traditional cookbook-style laboratory exercises in the undergraduate biology curriculum. The COVID-19 pandemic has highlighted the difficulty of implementing these projects during times of crisis. The quick transition to online learning during the pandemic afforded us a unique opportunity to develop an alternative version of our CURE for the online environment and to compare the efficacy of our CURE on learning gains in online versus in-person learning situations. Compared with a previous semester, our data suggest no significant differences in learning gains between students who participated in a hands-on CURE and an online CURE. Taken together the data suggests an avenue for CURE implementation even while teaching in online or hybrid formats. We discuss strategies that made the CURE successful in the online format and offer suggestions for how to adapt such activities for online or hybrid courses.

INTRODUCTION

There are barriers to the execution of laboratory courses in times of emergency when courses transition to an online format. Just as the pandemic forced colleges to create online and hybrid learning models, it is likely we will see courses offered partially or fully online in the future. Additionally, rapid transition from in-person to online instruction will remain essential for different reasons, such as in the case of weather-related closures (e.g., hurricanes) or with a newly cautious approach to public health concerns. Due to the COVID-19 pandemic, the course-based undergraduate research experience (CURE) we developed underwent a rapid transition from in-person to remote instruction. Here we provide details of the challenges we encountered in the transition and provide suggestions for future implementation in fully online or hybrid teaching environments.

PROCEDURE

In this CURE, students develop skills to assess exposure to environmental chemicals found in personal care products, providing students an opportunity to apply traditional skills from chemistry laboratory courses to an area of research that they can relate to. This semester-long set of modules is contained in an undergraduate Organic Chemistry II laboratory at a small teaching-focused institution. However, a similar approach can be adopted for courses in biochemistry, analytical chemistry, etc. All standard safety protocols for chemistry laboratories are followed for this course.

As originally designed, students participate in hands-on cookbook-style labs to learn about sample extraction and detection methods (1) (Fig. 1). The coverage of different extraction methods and analytes in cookbook-style labs prepares students for introduction to the CURE. In this guided CURE (2), faculty members determine the research question in advance (i.e., what kinds of phthalate exposure result from use of personal care products?) largely due to limitations imposed by human subjects research such as time to IRB approval. However, CURE students have the independence to determine the methods of analysis (i.e., how will samples be extracted?; how are data normalized?), to draw conclusions based on their class-pooled data, and to propose directions for future research (such as changing the analyte or source of exposure, etc.). Also, neither student nor faculty knows the "answer" when beginning the project.

As laboratory courses move to remote instruction, challenges arise. This CURE was implemented as an in-person course in spring 2019. Our spring 2020 COVID-interrupted term began in person, and students were able to perform the canned laboratories by hand. However, all work on the CURE was reformatted into remote instruction (Fig. 1). As multiple activities in the sequence require equipment or materials that are unavailable to students at home

*Corresponding author. Mailing address: College of Arts and Sciences, Lynn University, 3601 N Military Trail, Boca Raton, Florida 33431. Phone: (561) 237-7489. E-mail: ckorte@lynn.edu.
Received: 17 December 2020, Accepted: 12 February 2021, Published: 31 March 2021
†Supplemental materials available at http://asmscience.org/jmbe

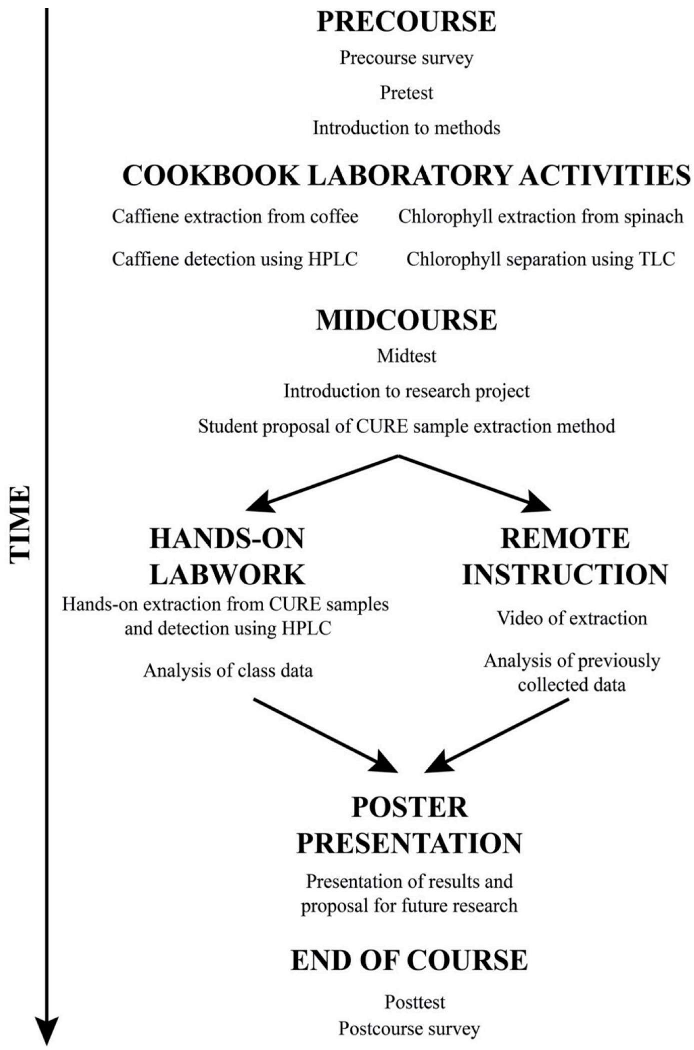

FIGURE 1. Timelines for our CURE-embedded course with hands-on lab work or with remote learning. For this project, students analyze real human urine for phthalate exposure following use of nail polish. Phthalate concentrations are measured using HPLC, and the class-collected data are analyzed. Students also do small group work: proposing authentic extraction methods and presenting a group poster detailing results, including proposing future research directions. TLC, thin-layer chromatography.

(e.g., high-pressure liquid chromatography [HPLC], human samples), detailed video demonstrations were provided to students to review the processes. A challenge for the faculty was the sudden closure of the university, removing access to the facilities to run or prepare samples. Because this CURE was previously run, we had ample data to provide to students. In addition, the sudden switch to remote instruction made group work and synchronous instruction difficult to coordinate for students and faculty. To overcome this, lectures were recorded and posted on the learning management system (LMS) to allow students a full week to access and complete those parts independently. The instructor was available during class time and office hours to answer questions about the material. The final group poster presentation was converted to an independent project to meet the needs of students who were unable to attend class (i.e., different time zones, childcare, etc.). Overall, flexibility was key in this sudden move to online learning; the videos allowed students to work at their own pace and provided opportunity for students to revisit course material. The supplemental document (Appendix 1) provides specific details on this adjustment in assignments.

This CURE was implemented in the classroom in spring 2019, resulting in student learning gains (1). In the spring 2020 semester, further student success data from the CURE was to be collected; however, due to the COVID-19 pandemic, the mid-semester transition to remote instruction created a pseudo-experimental setting to compare student performance across semesters in on-campus versus remote learning conditions. Participants (2019, $n = 29$; 2020, $n = 39$) were recruited into the study at the beginning of each term. After providing informed consent (IRB #18.34), students completed a pretest consisting of short answer questions written based strictly on the learning outcomes and content of the laboratory course rather than on organic chemistry lecture course content. Students then completed the course as designed (2019) or with transition to remote learning (2020) (Fig. 1). An identical midtest was performed after a sequence of cookbook labs. After completion of the CURE, students again completed the identical posttest. All exams were administered using LockDown Browser. Before transitioning to remote learning, exams were proctored in person. Afterwards, exams were administered online synchronously in the student's home location with online proctoring.

CONCLUSION

We looked at exam spread for pre-, mid-, and posttests across both academic terms in Figure 2. Exam scores significantly improved through the duration of the term, with scores on the midtest higher than scores on the pretest, and scores on the posttest higher than scores on the midtest. However, this pattern did not differ between the 2019 in-person and 2020 remote groups, and there was no difference in exam averages across the two groups, suggesting that the transition to remote instruction did not negatively impact student learning. This study highlights that CUREs can be successfully transitioned, or even fully implemented, in online formats while maintaining positive impacts on student learning. Although administered under somewhat different circumstances, previous work by Kirkpatrick et al. (3) determined that there was no significant difference in the positive impacts on students' attitudes between students who completed a computer-based CURE versus a bench-based CURE. Our results suggest similarities in learning gains as well.

In the spring 2021 semester, this course, like courses at many colleges around the world, will experience additional challenges. At our university, students have the option of

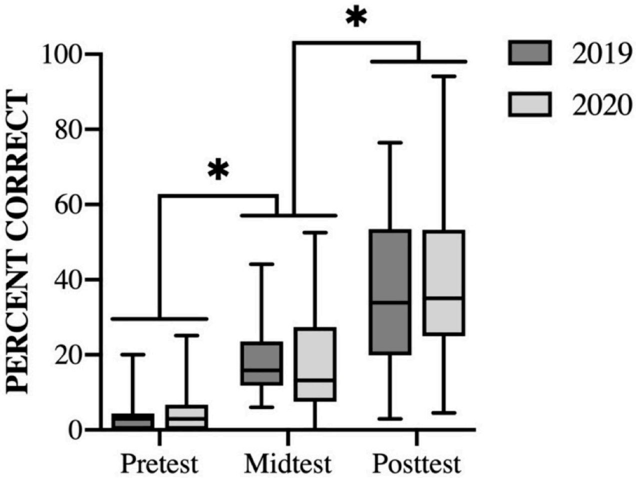

FIGURE 2. Boxplots of exam spread pre-, mid-, and post-course for each academic term (2019, $n = 27$; 2020, $n = 37$). Whiskers indicate minimum to maximum scores, the boxes indicate 25th to 75th percentiles, and middle lines indicate median scores. *, $p < 0.001$. Exam scores significantly improved through the duration of the term [$F(2, 124) = 138.92$, $p < 0.001$]; follow-up t tests with Bonferroni's correction confirmed that the midtest scores were higher than scores on the pretest [$t(62) = 9.97$, $p < 0.001$], and scores on the posttest were higher than scores on the midtest [$t(62) = 9.62$, $p < 0.001$]. This pattern did not differ between the 2019 in-person and 2020 remote groups (2, 124) = 0.425, $p = 0.655$, and there was no difference in exam averages across the two groups, $t(62) = 0.17$, $p = 0.87$.

either attending a hybrid course in person or completing the course remotely. To maximize the hands-on component of this course, we plan to combine synchronous instruction with asynchronous instruction on alternating days. Parts of this guided CURE, such as HPLC use, will be converted to asynchronous remote work by providing students with a recorded lecture, video demonstration, and post-lab questions. Other components will be synchronous but need to accommodate both remote and in-person students (see Appendix 1 for examples). For group assignments, all students will attend class synchronously. Students will work together during class time in Zoom breakout rooms regardless of attendance mode. All students will complete the same assessments. We will continue measuring the effectiveness of this guided CURE in this format.

SUPPLEMENTAL MATERIALS

Appendix 1: Laboratory format and transitional changes, including example data

ACKNOWLEDGMENTS

This research is supported by the Roberta Williams Laboratory Teaching Initiative Grant awarded by the Association for Biology Laboratory Education, 2018. This research was presented as a poster at the Society for the Advancement of Biology Education Research annual conference in July 2020. We gratefully acknowledge Tara Lunsford and Joshua Noriega as undergraduate research assistants on this project. We have no conflicts of interest to declare.

REFERENCES

1. Doctor EL, Lehman M, Korte CS. 2020. CUREing exposure to environmental chemicals from personal care products. Adv Biol Lab Educ 41. doi:10.37590/able.v41.extabs66
2. Brownell SE, Kloser MJ. 2015. Toward a conceptual framework for measuring the effectiveness of course-based undergraduate research experiences in undergraduate biology. Stud High Educ 40(3). doi:10.1080/03075079.2015.1004234
3. Kirkpatrick C, Schuchardt A, Baltz D, Cotner S. 2019. Computer-based and bench-based undergraduate research experiences produce similar attitudinal outcomes. CBE Life Sci Educ 18(1). doi:10.1187/cbe.18-07-0112