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CURE in a Box: an Online CURE for Introductory Biology Majors That Incorporates *Vision and Change*†

Kyle F. Bennett*, Paul E. Arriola, Tamara L. Marsh, Patrick M. Mineo, Stacey L. Raimondi, and Corey L. Shaffer
Department of Biology, Elmhurst University, Elmhurst, IL 60126

Course-based undergraduate research experiences (CUREs) help fulfill the recommendation of *Vision and Change* for biology curricula to focus on key concepts and skills to better prepare students for careers in the sciences. However, the COVID-19 pandemic has forced many schools to move instruction online, highlighting the dearth of resources available for offering a CURE for introductory biology outside of the traditional laboratory-based setting. Here, we present a revision of our first-semester General Biology laboratory for a synchronous online setting where students perform a research-based wet lab component at home using an affordable preassembled kit while still meeting the CURE learning objectives. This template can be utilized by other colleges and universities that are looking to offer a safe, reliable, and affordable CURE in their introductory biology courses whether in a virtual or face-to-face environment.

INTRODUCTION

Recommendations from *Vision and Change* (V&C) (1) are leading many biology departments to revise their curricula to develop more course-based undergraduate research experiences (CUREs). Documented benefits of CUREs include increased understanding of key biological concepts, developing competence in the process of science, laboratory skills, and analytical abilities (2), and increased retention and graduation rates (3), including in underrepresented groups (4). The COVID-19 pandemic has forced many schools toward online instruction, but few resources exist to offer research-based lab experiences in an at-home setting. Most commercially available lab kits are overstructured and simplistic and do not have the integrated development of hypotheses, experimental design, data analysis, or troubleshooting that are the hallmarks of scientific research. We sought to create a take-home CURE kit that would allow students to have this experience.

At Elmhurst University, General Biology I is a majors introductory-level core biology course populated primarily by first-year students with no microbiology lab experience. It has been revised for active learning centered on major concepts and core competencies outlined in V&C. Part of this revision included adopting the V&C-aligned textbook *Integrating Concepts in Biology* (ICB) by Campbell, Heyer, and Paradise, which has long-term positive impacts on students' conceptual expertise (5). We previously described developing a lab focused on the application of the scientific method while developing students' experimental design and methodological skills (6). The shift to online teaching due to the COVID-19 pandemic and the inability to maintain physical distancing in the laboratory required us to retool the lab to have students perform wet lab work at home. This revised version of the lab is a safe, reliable, and affordable option for colleges and universities of all sizes to engage students in an authentic research experience during the COVID-19 pandemic and beyond, while still achieving the learning objectives of our CURE-based in-person course.

PROCEDURE

Our semester-long General Biology I laboratory investigates whether *Saccharomyces cerevisiae* can develop tolerance to chemotherapy drugs in one semester (6). During the summer of 2020, we reimagined the lab for at-home completion by developing a kit that included all the necessary materials for the activity which could be picked up from our campus or shipped to a student's home (see Appendix 1 for kit contents and cost). Rather than use expensive and potentially unsafe chemotherapeutics in an uncontrolled environment, the lab was modified to determine whether commercially available yeast (Red Star Yeast, Milwaukee, WI) could develop tolerance to common household cleaners

*Corresponding author. Mailing address: Department of Biology, Elmhurst University, 190 Prospect Ave., Elmhurst, IL 60126. Phone: 630-617-3592. E-mail: kbennett@elmhurst.edu.
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after selection by continuous low-level exposure. We chose cleaning products based on availability, effectiveness based on initial faculty experimental results, and potential differences in mode of action. As in our previous iteration, weekly requirements included students developing a hypothesis, designing and setting up an experiment, collecting data, recording results, and forming conclusions that highlighted how they applied scientific methodology (see Appendix 2 for syllabus). Lab time is synchronous online in order to ensure that students are receiving live instruction and feedback from faculty to alleviate safety concerns. Students may also refer to online prerecorded videos showing each step of the procedure.

During the first 2 weeks of lab, students learn biosafety protocols (see Appendix 3 for student handout) and how to maintain yeast cultures in broths and plates starting from a slant culture provided with the kit, using aseptic technique and sterile prepackaged materials. Subsequently, students research the active ingredients of the cleaning products and develop hypotheses regarding their effectiveness based on their mode of action to prepare for the experiment. The CURE requires that students complete a disc diffusion assay with common household cleaners applied to sterile paper discs and examine zones of inhibition after incubation to obtain a baseline of inhibitory action from a full-strength exposure. Students then are guided in the development of minimum inhibitory concentration assays with one or more effective products identified from the disc diffusion assay. Cell growth is determined visually against high-resolution images of known cell concentration standards posted on the course learning management system. The students repeat the transfers of previously exposed cells into new tubes of the earlier identified cleaning product at the minimum inhibitory concentration for 5 weeks. At the semester's conclusion, the disc diffusion assay is repeated to determine whether the selective pressure has shifted the population's ability to grow in the presence of the cleaning product. The students pool the class data into a common spreadsheet that is then used for instruction in statistical analysis.

At the midpoint of the term, students write a summary of their experiments, linking them to the big ideas of biology that structure the ICB textbook to reinforce how lecture and lab are integrated. At this point, students are increasingly proficient in maintaining yeast cultures and can design other experiments to perform with this model organism. For example, students use both their control and cleaning product–exposed yeast cultures to observe fermentation rates. This experiment dovetails with the metabolism content in the lecture and allows students to determine whether overcoming inhibition by household cleaners impacts metabolic processes. Modules to connect any of the big ideas of biology presented in the ICB textbook can be incorporated into the lab schedule as needed. At the end of the semester, student groups prepare and present a poster discussing their findings to the rest of the class and departmental faculty.

CONCLUSION

Offering majors-level biology online is challenging under any circumstances, as is offering an authentic research experience of any kind. In our three years of using a CURE model, we have found that our students have a greater appreciation for the scientific process and have come to see novel research as something that they can do, even as first-year undergraduates. They also experience the excitement of not knowing the experimental outcome and learn more about what it means to conduct real science. Losing that important aspect of our introductory biology sequence was not something we were willing to accept; however, the move to a fully online environment due to COVID-19 threatened that commitment. The revision of this lab to a "CURE in a box" allows the faculty to maintain its commitment to V&C and the practical application of scientific methodology while keeping students physically distanced. Furthermore, due to the affordability of this kit, it can be used in future academic terms, providing the flexibility for teaching additional sections of the course without using our limited lab space. Kit preparation and assembly is scalable, assuming the institution has dedicated lab support. Our lab coordinator, along with undergraduate lab assistants, prepared the materials and assembled 100 kits in approximately 275 person-hours over 3 weeks. This lab model provides an affordable option for schools of all sizes to provide students an off-site course-based research experience.

SUPPLEMENTAL MATERIALS

Appendix 1: Table of equipment, supplies, and costs
Appendix 2: Lab syllabus
Appendix 3: Safety protocols

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