DOI: https://doi.org/10.1128/jmbe.v20i1.1636

JMBE Journal of Microbiology & Biology Education

A One-Year Introductory Biology Majors' Lab Sequence Incorporating *Vision & Change*†

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The introduction of Vision and Change by AAAS and the recommendation that biology departments amend their curricula to focus on key concepts and skills necessary for graduates have led to a re-envisioning of introductory curricula across the nation. Many of the "standard" biology text books have realigned their focus with Vision and Change, while new texts have emerged that completely revise how we teach introductory biology majors. One such textbook is *Integrating Concepts in Biology* (ICB), by Campbell, Heyer, and Paradise. Many departments, including ours, have adopted this text as a novel way to teach biology majors, focusing on active learning, the scientific method, and specifically, understanding data. However, with all of these revisions to biology textbooks, there have been no revisions or insights into corresponding labs for a typical 1-year introductory course sequence. Here, we provide a description of our 1-year lab sequence, emphasizing the scientific method and novel research, with a focus on the five "Big Ideas" presented in ICB. By removing the "cookbook" labs typical of most introductory laboratory courses, we found that this system better emphasized the focus of Vision and Change and, concomitantly, student appeared to enjoy the lab sequence and see the relevance to class material better, compared to previous years. We believe that this lab organization is a simple design that is not resource-intensive and can be utilized at schools of any size or budget.

INTRODUCTION

The *Vision and Change* document and several studies on best practices in teaching science have clearly shown that biology curricula need to be revised to focus on learning and applying key concepts rather than memorizing details (1, 2). To that end, many introductory biology textbooks have been revamped and/or rewritten to incorporate these key concepts. Additionally, a new textbook, *Integrating Concepts in Biology* (ICB), by Campbell, Heyer, and Paradise, has been developed based on the principles of Vision and Change (3). This textbook is organized around five "Big Ideas" of biology—Information, Evolution, Cells, Homeostasis, Emergent Properties—at the Cellular/Molecular, Organismal, and Population/Ecosystem levels. While this text has revolutionized how introductory biology is taught to undergraduates, and studies have shown that learning concepts rather than details has improved outcomes (4), a similar revision to introductory lab sequences has not been accomplished. To that end, upon adoption of ICB by our department, a one-year lab sequence was designed that corresponds to the learning of key concepts rather than rote memorization of details. It was determined that the overarching goal of any introductory science lab should be to learn and apply the scientific method, incorporate key lab skills as part of the process, and provide a novel research experience that emphasizes experimental design and troubleshooting for every student.

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Received: 7 June 2018, Accepted: 30 November 2018, Published: 26 April 2019.
†Supplemental materials available at http://asmscience.org/jmbe

PROCEDURE

In the first semester lab sequence, the goal of the lab was to determine whether commonly available yeast could develop chemotherapy resistance in one semester. Yeast was chosen rather than the more commonly used *Escherichia coli* for safety considerations since this was the students' first experience using aseptic technique and accidents were expected. Each lab section was given a different strain of yeast obtained from local stores, and each week students wrote a hypothesis, set up an experiment, collected data, and recorded results and conclusions, placing the entire focus of the lab on the scientific method. After learning and practicing aseptic technique, students set up a disc-diffusion experiment utilizing a fungicide (Benomyl) as well as a few common chemotherapeutics (5-fluorouracil [5-FU], methotrexate, cyclohexamide) to examine zones of inhibition as a cell death baseline measurement marker. As part of the initial set up, students were asked to research the mechanism of action of the drugs to make hypotheses about which drug would be most effective. Students subsequently set up a minimum inhibitory concentration (MIC) assay with the most effective drug (5-FU), providing experience with measurement and dilution skills. The rest of the semester was spent growing yeast at the MIC, measuring absorbance weekly as an indicator of cell growth, and finally repeating the initial disc diffusion assay to determine whether resistance was achieved throughout the term. At the halfway point of the semester, students wrote a summary of what was happening in their cultures and correlated observations to the class material. This activity allowed them to discuss the Big Ideas of Information (5-FU regulates thymidine synthesis), Evolution (specifically clearing up misconceptions on how drug resistance evolved in the population), and Cells (focusing on the structure of the yeast that allowed them to resist so many other drugs). This write-up aligned with the Big Ideas that had been covered in class to that point and was a turning point for students, where many acknowledged that they finally understood the procedures and rationale of the exercise. At the end of the semester, each lab group prepared and presented a poster discussing their findings with the rest of the class and departmental faculty.

The second semester of the lab emphasized organismal and population-level biology centered on the Big Ideas of Emergent Properties and Homeostasis. Recognizing that the observational skills gained in a traditional lab are valuable, students began with a series of two anatomy and identification labs. Rather than broadly covering multiple phyla, these labs focused on examining and identifying the model organisms that were the basis of the semester-long lab project. Subsequently, the research project began with a goal of determining the impact of competition on population growth in freshwater aquatic ecosystems. Microcosms were set up with daphnid crustaceans and freshwater annelids (5). Each lab section was assigned a freshwater annelid species: *Aeolosoma, Dero,* or *Stylaria*. Within each lab section, the lab groups chose different daphnid species: *Daphnia pulex, Daphnia magna, Ceriodaphnia dubia,* or *Moina brachiate*. All experimental taxa are inexpensive and commercially available. Students generated hypotheses and designed microcosm experiments to test their hypotheses. The experiments lasted for approximately four weeks, and results were presented in a full lab report. As data were generated, much of the lab periods were dedicated to data analysis and instruction on scientific writing. Students submitted multiple drafts of the paper to provide a developmental revision process. A second experimental exercise lasting two weeks examined daphnid physiology, a topic that coincided with physiology content in the lecture. The final lab period of the semester was a class discussion. Lab sections could see each group's results and compare their daphnid population's response to the other groups' results. The use of a shared organism, in this case the annelid, modeled large scale academic research projects in which many collaborators take different pieces of a project.

CONCLUSION

While the faculty were initially concerned that focusing on only one item in lab would make it "too easy," instead we found that the students ended the semester with a far stronger understanding of the scientific process than ever before. At the beginning of the year, students were initially shocked, and even upset, when they learned that the faculty did not know whether the experiment would be successful, but soon they learned to appreciate the realities of novel research, where anything can happen. Furthermore, the students learned the importance of model organisms in answering varied questions relating to the five "Big Ideas" in biology, and some have gone on to utilize these organisms in other projects they are doing outside of class. Most importantly, this lab allowed students to take part in the entire scientific method, from observation/gathering of background information and formation of a hypothesis to presentation/publication of data. There were weeks where the experiment failed and the students had to redo everything, and there were weeks where surprising or inconsistent results were obtained. This lab sequence taught students that science does not happen in a three-hour block, but is instead a process that happens over time. Finally, the students learned that being a scientist and conducting novel research means not knowing the answer before starting the experiment, but by synthesizing and applying information previously known, they can place their results in context and contribute to the field of study, even as first-year undergraduates.

SUPPLEMENTAL MATERIALS

Appendix 1: Lab syllabus

ACKNOWLEDGMENTS

The authors declare that there are no conflicts of interest.

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