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Guided Homework Assignments Prepare Students for Flipped Introductory Biology Classroom†

Stacey L. Raimondi*, Kyle F. Bennett, Merrilee F. Guenther, Kelly Ksiazek-Mikenas, and Patrick M. Mineo
Department of Biology, Elmhurst University, Elmhurst, IL 60126

INTRODUCTION

The National Science Foundation publication of *Vision and Change* and studies promoting increased learning for STEM students have led to changes and innovations in curricula across STEM disciplines (1, 2). One example of that innovation includes the introductory biology textbook, *Integrating Concepts in Biology* by Campbell, Heyer, and Paradise, which uses the novel approach of presenting original research through figures and data to teach biological concepts rather than through memorizing facts (3). This textbook has already been shown to increase students' understanding of biological concepts and ability to organize biological ideas at a deeper level compared with a traditional textbook (4). It also lends itself well to a flipped classroom model to help improve learning and remove barriers among students (5). However, for many students, critically analyzing figures and data is a drastic change from anything they have done before, and the process can lead to frustration if they are not guided through the material. This frustration can be amplified by the expectation that students make the first attempt at understanding the material independently before coming to class, which is imperative for a flipped classroom to succeed. To alleviate those issues and allow students to engage in critical discussions of ground-breaking experiments and scientific data in class, we developed a novel homework assignment. This assignment guides students to a better understanding of the figures and data prior to class and can be utilized across STEM disciplines.

PROCEDURE

Our first-year biology majors' course has multiple sections (three to four per semester), each with approximately 24 students, and is taught by five different teaching faculty. Based on prior research, we originally used pre-class online reading quizzes to test student knowledge and ensure that students were prepared for a flipped classroom model (6). The reading quizzes could be taken multiple times and were meant to incentivize reading before class. Unfortunately, the faculty quickly realized that many students were taking the quizzes multiple times to get a perfect score, without doing the expected reading. A student might have 20 or more attempts at a single quiz within a matter of minutes, thus negating any actual learning and preparation that the faculty members were hoping to achieve. The professors teaching the class observed no correlation between reading quiz scores, preparation for class discussions, and in-class quiz/exam grades.

During the following academic year, the faculty discontinued the use of the reading quizzes and instead instituted written homework due before each class period. The written homework asked students to explain the learning objectives provided in each section of the text. While the students were instructed to use the data and figures throughout each section of the text to explain each of the learning objectives, only a select few were able to achieve this goal. Most students focused on the summary of learning objectives provided in a final paragraph of each section of the book without truly understanding the figures and data presented in that unit. Implementing a flipped classroom pedagogy was difficult in this situation because the students were not prepared to discuss the figures and relate the original experiments to the learning objectives, which is the primary focus of class time. As a result, the course defaulted into a more lecture-based format, which deviated from the original goal of incorporating *Vision and Change* and frustrated faculty and students alike.

To ensure that students gained an understanding of the figures/data prior to class, the homework assignment was modified again the following academic year to a new template format. This general homework template (provided in Appendix 1) can be utilized in any course that incorporates data analysis. In this format, the focus for students' pre-class work is an analysis of each figure, in which they describe the hypothesis, methods, results, and conclusions for each experiment that produced a graph or table. On the first

*Corresponding author. Mailing address: Department of Biology, Elmhurst University, 190 Prospect Ave., Box 133, Elmhurst, IL 60126. Phone: 630-617-3323. E-mail: raimondis@elmhurst.edu
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day of the semester, faculty provide a sample figure and ask students to work in groups during class time to determine the hypothesis, methods, results, and conclusions. This gives the students a chance to practice developing their analytical skills with faculty and peer help before doing it on their own. We also provide students with a sample of completed homework so that they can better understand our expectations for the assignment. The number of figures students analyze for their homework will vary from section to section. In some cases, the faculty members believe it is important for students to be prepared to discuss all figures in a section. In other situations, there may be one or two key figures that illustrate the major concepts and students will only be required to analyze those figures. The homework template is highly modifiable to allow for any number of figures to be analyzed prior to a particular class. The new homework format also requires students to relate examples to the learning objectives and to identify the "big ideas" of biology that are illustrated by the experiments, with the hope that students will ultimately remember that the figures and details are not discrete, but rather relate back to a major biological concept. Two specific examples of completed homework assignments are provided in Appendix 2 for faculty utilizing *Integrating Concepts in Biology* (7).

Because the goal is for students to come to class prepared, these assignments are graded primarily on completion and effort rather than accuracy. Full credit is given if faculty members see an assignment submitted on time with a hypothesis, method, result, and conclusion for each figure, as well as a comprehensive summary of how each figure illustrates the learning objectives of that section, regardless of incorrect answers. The faculty members acknowledge that the students may not fully understand every experiment and figure before they come to class, but they should have a foundation of knowledge that allows them to participate in a flipped classroom discussion. Students submit their homework online via the classroom management system prior to each class (either two or three days a week, depending on the course schedule) and faculty randomly select approximately one assignment per week to provide comments and a grade, with more assignments collected at the beginning of the semester to provide feedback in the learning process. In a 14- or 15-week semester, faculty only count the top 10 scores in the final course grade to allow for student mistakes or missing homework. Together, these assignments allow for student learning in a low-stakes environment without punishing the overall course grade during the learning process. Furthermore, because of the ability to select a certain type/number of figures to analyze, as well as only grading a portion of the total assignments, it allows the homework to be scaled to large and small classrooms alike. Students are encouraged to use the homework as their notes for class, adding to them during the discussion, reviewing them after each class, and using them as study guides for exams.

RESULTS AND CONCLUSIONS

Achieving the desired high level of critical analysis in this introductory course has been challenging. Fortunately, because less class time is now needed to discuss the details of the experiments—information already known from the homework—faculty have been able to focus on synthesizing experiments and learning objectives. More interesting and robust conversations in class have resulted from better student preparation prior to class. While students initially complained about the amount of time spent on homework for the course (averaging at least three hours per assignment), the students acknowledged to faculty that more time spent preparing for each class meant less "cramming" at exam time. This process ensures students engage with the material at least three times: with the homework, in class, and during post-class review. By the end of the semester, personal student feedback indicated that most students became far more efficient with their time and were not only able to complete the assignments quickly and accurately but also increase their participation in class discussions and on written assessments.

At the start of this course, students are typically uncomfortable with data analysis and comprehension because they have never been asked to do this in a science class before. Therefore, it is extremely important for faculty to provide the necessary guidance to help students become active rather than passive learners. Indeed, the ability to synthesize and evaluate the data presented in tables and figures, the highest level of Bloom's taxonomy, is not something that the typical undergraduate student enters college being able to do. By having the students focus on lower-level Bloom's taxonomy in their homework (knowledge and comprehension of an experiment), the faculty can spend time on application, analysis, synthesis, and evaluation in the flipped classroom, a far better use of faculty time and expertise. This approach also encourages students to frame their study efforts around the section's learning objectives. This unique homework assignment template guides introductory students to successfully engage with difficult material in a new learning environment and promotes robust in-class discussions in a flipped classroom environment. Furthermore, this assignment can be modified to work in a flipped classroom environment for any course, whether in-person or online and, therefore, can be a useful tool to faculty across STEM disciplines.

SUPPLEMENTAL MATERIALS

Appendix 1: Sample general homework assignment
Appendix 2: Sample completed homework assignments

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