Improvement in Student Data Analysis Skills after Out-of-Class Assignments†

Kristen L.W. Walton
Department of Biology, Missouri Western State University, St. Joseph, MO 64507

INTRODUCTION

A growing consensus in the biology education community calls for the transformation of undergraduate biology education (2, 7). One of the recommendations of reports such as the Vision and Change report (2) is to expose undergraduate biology students to the process of science throughout the curriculum, including reading primary literature and analyzing experimental data. While biology majors are the primary focus of this transformation, biology courses are also foundational for several other majors, including allied health majors. These students will also benefit from increased exposure to data analysis, both to increase their scientific literacy as citizens and to support careers in allied health professions. Increasing undergraduate students’ information literacy also supports the increasing emphasis on practicing evidence-based medicine (1). A recent review of introductory biology textbooks demonstrates that relatively few experimental data figures are included (8); although a similar analysis of figures in allied health microbiology textbooks was not found in a search of the current literature, similar trends are likely. Thus instructors must often supplement textbook figures with primary literature to expose students to experimental data.

Many models of introducing students to analysis of data from the primary literature have been published. These models range from using discussion of journal articles to underscore important concepts in the course (3), to replacement of a laboratory section with article discussions (10), to entire courses devoted to teaching students how to critically read and analyze primary journal articles (4). The decision about how much time to devote to learning process skills such as data analysis must be weighed by the individual instructor and department. However, it is often not feasible for a course such as an allied health microbiology course to devote a significant portion of the laboratory section to data analysis and journal article discussion, nor is it always easy to introduce an additional course to another department’s major. Giving students out-of-class assignments that require analysis of data from the primary literature is one way to introduce this skill without taking substantial time away from other course goals and content. However, it is important to assess whether this can have a positive impact on student skills. The current study used a small number of out-of-class assignments to build student skills in understanding and analyzing data figures from the primary literature. The effectiveness of this approach was assessed using a pre- and posttest of student data analysis skills.

PROCEDURE

Students in our allied health microbiology class are typically second- or third-year pre-nursing students, with one nonmajors general biology and one nonmajors general chemistry class as prerequisites. Due to a rotation of teaching assignments, the author (K. Walton) taught the lecture and all lab sections in the first semester of this study; in the other two semesters included in this study, the author taught one or two lab sections of the course and a different instructor taught the lecture and one or two lab sections. The other instructor agreed to administer the assignments and pre- and posttests. All assignments, pretests, and posttests were graded by the author. This study was approved by the Missouri Western State University IRB (protocol #783).

Assignments were designed to complement topics being covered in the lecture portion of the course at the time and were designed to build in complexity. The first assignment included questions about background information and one selected figure from a journal article (6; Appendix 1). The second assignment required students to interpret information in table format and read a short, clinically-oriented primary journal article with a flowchart and data tables (5; Appendix 2). The last assignment was adapted from a publicly available resource from NOVA and included several line graphs and a photograph of gel electrophoresis of polymerase chain reaction (PCR) products (11; Appendix 3). No class time was used to discuss the assignments once they were handed out, but students were encouraged to seek help from the instructor outside of class with any questions. They were given written feedback on the grad-
ed assignments, which were returned within a week. They were not directly tested on data analysis on exams or later course assessments. The pre- and posttest were adapted from a published, validated instrument for data analysis skills in molecular biology (9). This multiple-choice format test was designed to include questions over a range of types of data, including line and bar graphs, gel images, and flowcharts using microbiology experiments as the context (Appendix 4). As an internal control, several questions were included that did not directly relate to the assignments given during the course. The pre- and posttests were given in the first and last weeks of the semester, respectively. Mean scores on the pre- and posttests and on individual questions were tested for statistically significant differences by a paired t-test.

Across three different semesters, mean student scores on the data analysis pretest were near 50% (Fig. 1). Mean posttest scores improved by 7.9 to 9.3% ($p < 0.05$ for each semester by paired $t$-test). Figure 2 shows the pre- and posttest scores on the 15 individual questions for a typical semester (fall 2010). Similar trends were observed in the individual question scores from the other semesters. Interestingly, the questions that consistently showed the greatest increase in correct responses were one question testing higher-level skills in predicting an appropriate follow-up experiment and two questions involving correct interpretation of a flow diagram. Both of these types of questions directly related to the types of data and questions asked in the assignments. Several questions showed little change in the number of correct responses between the pre- and posttest; most notably questions 1 to 3, which tested students’ understanding of simple line graphs. Students typically scored well ($\geq 71\%$ for all three questions across all three semesters) on these questions in both the pre- and the posttest.

**CONCLUSION**

Incorporating an additional pedagogical goal into a course often presents a challenge: if there is no additional time added to the course, the instructor must either take time away from other course goals or use strategies that can address the new goal without taking a significant amount of course time. This study provides evidence that a small number of assignments involving data analysis can result in measurable gains in student skills in this area. In addition, the data analysis test designed for this study is challenging for students at this level, but can measure improvement in data analysis skills related to the assignments used.

**SUPPLEMENTAL MATERIALS**

Appendix 1: Botulism case study

Appendix 2: Handwashing case study

Appendix 3: Antibiotic resistance case study

Appendix 4: Data analysis test

**ACKNOWLEDGMENTS**

This work was presented in preliminary form as a poster at the Association of College and University Biology Educators (ACUBE) 2015 annual meeting, St. Joseph, MO. K. Walton would like to thank the American Society of Microbiology’s Biology Scholars Program (NSF Award #0715777) for helping her develop her research ideas, and Dr. Jason Baker, Missouri Western State University, for administering assignments and surveys. The author declares that there are no conflicts of interest.

**REFERENCES**

1. Aglen, B. 2016. Pedagogical strategies to teach bachelor students evidence-based practice: a systematic review. Nurse Educ. Today 36:255–263.
2. **American Association for the Advancement of Science.** 2011. Vision and change in undergraduate biology education: a call to action: a summary of recommendations made at a national conference organized by the American Association for the Advancement of Science, July 15–17, 2009. Washington, DC.

3. **Breakwell, D. P.** 2003. Using the primary literature in an allied health microbiology course. Microbiol. Educ. 4:30–38.

4. **Hoskins S. G., L. M. Stevens, and R. H. Nehm.** 2007. Selective use of the primary literature transforms the classroom into a virtual laboratory. Genetics 176(3):1381–1389.

5. **Luby S.P., M. Agboatwalla, J. Painter, A. Altaf, W. L. Billhimer, and R. M. Hoekstra.** 2004. Effect of intensive handwashing promotion on childhood diarrhea in high-risk communities in Pakistan: a randomized controlled trial. JAMA 291(21):2547–2554.

6. **Moeller R., P. Setlow, G. Reitz, and W.L. Nicholson.** 2009. Roles of small, acid-soluble spore proteins and core water content in survival of *Bacillus subtilis* spores exposed to environmental solar radiation. J. Appl. Envir. Micro. 75(16):5202–5208.

7. **National Research Council.** 2003. BIO 2010: transforming undergraduate education for future research biologists. The National Academies Press, Washington, DC.

8. **Rybarczyk, B. J.** 2011. Building students' visual literacy skills: teaching beyond the textbook. J. Coll. Sci. Teach. 41(4):106–114.

9. **Rybarczyk B. J., K. L. W. Walton, and W. Heck Grillo.** 2014. The development and implementation of an instrument to assess students' data analysis skills in molecular biology. J. Microbiol. Biol. Educ. 15(2):259–267.

10. **Segura-Totten, M., and N. E. Dalman.** 2013. The CREATE method does not result in greater gains in critical thinking than a more traditional method of analyzing the primary literature. J. Microbiol. Biol. Educ. 14(2):166–175.

11. **WBGH/NOVA and Vulcan Productions.** Rx for Survival – Rise of the Superbugs Teacher Guide and Student Worksheet. www-tc.pbs.org/wgbh/rxforsurvival/series/teachers/pdf/rx_guide_superbugs.pdf Accessed 1/7/16.