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Using "Research Boxes" to Enhance Understanding of Primary Literature and the Process of Science †

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INTRODUCTION

There has been a major shift in life science education this past decade, and instructors are expected to place more emphasis on skills such as analyzing and interpreting data. This transformation has been facilitated in part by the publication of *Vision and Change*, which calls for more focus on interpreting and communicating results of empirical studies (1). These expectations can be a challenge for undergraduate students, who often focus on lower order cognitive skills such as remembering core knowledge. Given that the foundation of the life sciences is grounded in empirical studies and interpretation of experimental data, there is a continued need for collaborative learning activities that enhance these skills.

Recent approaches have emphasized the use of primary literature to facilitate an understanding of the process of science (2–10). A few examples include the CREATE strategy (Consider, Read, Elucidate hypotheses, Analyze and interpret data, Think of the next Experiment), Figure Facts (students focus more on figures in research articles and less on the text), and Research Deconstruction (students spend several weeks analyzing a research seminar and empirical data). While these approaches are effective at helping students better understand primary literature, they may require extensive in-class and out-of-class time and consideration of multiple papers, and they generally do not include rubrics for evaluating student work products.

This manuscript outlines a learning activity that encourages students to engage with the primary literature to better understand how science is conducted and communicated. Students who complete this activity read a primary research article, or selected parts of the article, and summarize the key components of one experiment in the article as a one-page figure, or "Research Box" (RB), similar to those found in major introductory biology textbooks (11). The RB activity outlined here helps students engage with the primary literature and facilitates an understanding of how conclusions are reached in the life sciences. By having students focus on a single experiment, this RB activity helps to minimize the tendency of students to feel overwhelmed when trying to understand complex empirical studies. The sample RB assignment and the associated assessment rubric can be used as a template for multiple RB activities throughout the semester.

PROCEDURE

The RB activity consists of a primary research paper chosen by the instructor (or by students themselves), a few guiding questions based on the paper, guidelines for students to create their own RB based on an experiment in the primary research paper provided, and an assessment rubric for the RB. Instructors may wish to provide a sample RB the first time they assign a RB activity. The purpose of the sample RB is to ensure that students are introduced to the major components, which include the following:

1. **Question** (the major question addressed by one experiment within the paper)
2. **Hypothesis** (based on previous observations)
3. **Null Hypothesis** (what should be observed when the hypothesis being tested isn't correct or supported)
4. **Experimental Setup** (a condensed version of the experimental design that lets the reader know in a simplified way how the experiment was set up and what observations or measurements were recorded)
5. **Prediction** (the predicted results based on observations that would support the hypothesis)
6. **Prediction of Null Hypothesis** (the predicted results based on observations that would NOT support the hypothesis)
7. **Results** (a brief representation of results, often in the form of a graph, table, or microscopic image)
8. **Conclusion** (interpretation of results of the selected experiment and an indication of whether or not they support the hypothesis)

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The guidelines for student-generated RBs should be brief, to allow for creativity, but also provide clear, unambiguous expectations. Suggested guidelines for students include:

- Be sure to include all of the key elements: question, hypothesis, null hypothesis, experimental setup, predictions based on hypothesis and null hypothesis, results, and conclusion.
- RB must fit on a single page.
- You may hand-draw your final RB or use drawing tools on your word processing program—whatever method is easiest for you is fine.
- Be sure to provide opportunities for all team members to help with this assignment! Although all students should be competent in all areas upon completion of this assignment, suggested roles include: interpreter (primarily responsible for interpreting the research paper); drafter (primarily responsible for creating the RB); manager (oversees other team members to make sure guidelines are being followed); and spy (checks in with other teams to see how they are interpreting the research article).

The sample RB assignment presented here (Appendix 1) is a template for instructors that can be easily modified by substituting a different research paper. The assessment rubric provided (Appendix 1) can also be modified to meet instructors' needs and can be incorporated into online course management systems to help streamline the assessment and feedback process. The sample RB assignment provided here is meant to be completed as a collaborative in-class activity, but can also be assigned to individual students. This particular RB activity was part of an introductory course for first-year students, and it was the first assignment of this sort that students had seen. Therefore, the paper chosen was short, was relatively easy to understand, and focused on a topic that many beginning biology students struggle with (namely, reproductive biology of mosses) (12). Figure 1 illustrates a RB constructed by a team of three students based on the assigned paper.

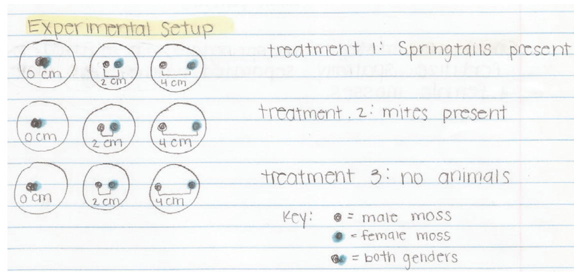
It is important that all team members contribute to the RB. Roles can be assigned by the instructor or the students ahead of time. Alternatively, each team can simply write a brief paragraph describing the role of each team member. For longer research papers with multiple experiments, instructors can have different teams focus on different experiments in the paper. Final RBs can then be shared among teams as part of a wrap-up synthesis discussion and can even be incorporated into a peer-review activity, where students evaluate other RBs based on the assessment rubric.

Question:
Is fertilization in mosses facilitated by microanimals?

Hypothesis:
Mites and springtails facilitate the transfer of sperm between mosses.

Null Hypothesis:
Mites and springtails will have no impact in the fertilization of mosses.

Experimental Setup:

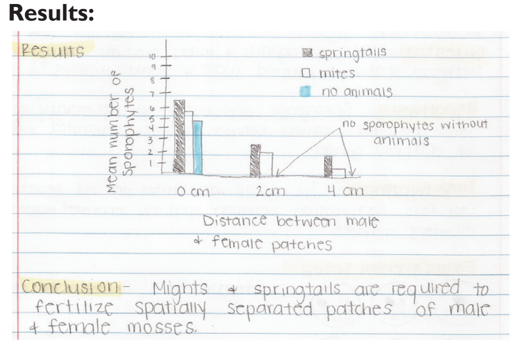


Male and female mosses set up at 3 distances (0 cm (united), 2 cm, and 4 cm) in plastic vials. This was replicated 3 times (9 vials total, 3 for each distance). Fast-moving springtails were added to the first 3 vials of different distances. Slow-moving orbital mites were added to 3 other vials of different moss distances. The final 3 vials of different moss distances had no microarthropods added.

Prediction:
Fertilization rates will increase at all distances for the vials containing microarthropods. The vials with springtails will show highest fertilization rates of all.

Prediction of Null Hypothesis:
The fertilization rates of the moss vials containing microarthropods will be the same as those without microarthropods.

Results:



The mean number of sporophytes decreased as the distance between the male and female patches increased. In each group, the vials with springtails produced the most sporophytes, followed by the vials with mites. The vials that contained no animals only produced sporophytes in the vial where the mosses were united.

Conclusion:
The vials containing microarthropods showed higher moss fertilization rates than the vials not containing microarthropods. The three vials containing springtails showed the highest fertilization rates of all. Microarthropods are shown to increase the range at which mosses can be fertilized by others, as well as increasing the fertilization rates of united mosses. The hypothesis is supported.

FIGURE 1. Introductory biology student-generated Research Box based on a recent paper on the role of microarthropods during sexual reproduction in mosses (12).

CONCLUSION

Students responded positively to RB activities, and indirect assessment from two separate institutions indicates that the majority of students agree or strongly agree that the RB activity helped them understand primary research articles and the process of science, as well as increase their understanding of fundamental concepts in biology (Appendix 2).

As the field of disciplinary-based education continues to focus more on the process of science and less on lower levels of Bloom's taxonomy (13), there will be a continued need for learning activities to be completed by individuals or teams that enhance students' understanding of the primary literature and experimental design. The learning activity outlined here provides instructors with a streamlined mechanism for accomplishing these goals that can be easily adapted by instructors to meet their individual course needs.

SUPPLEMENTAL MATERIALS

Appendix 1: Research box assignment
Appendix 2: Assessment

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