Supplemental Materials

for

The Biology Experimental Design Challenge: An Interactive Approach to Enhance Students' Understanding of Scientific Inquiry in the Context of an Introductory Biology Course

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Appendix 1: Sample card decks for the biology experimental design challenge.

**Figure S1.** Sample game decks for the Biology Experimental Design Challenge activity. (Top) Pictures of a bottle of water, a bottle of Gatorade®, and a group of athletes. Students might hypothesize, for instance, that consuming Gatorade® leads to greater endurance among athletes than consuming water. (Bottom) Pictures of a field of flowers and two different types of fertilizer. Students receiving this deck might choose to conduct an experiment to test which fertilizer leads to the greatest amount of plant growth over a specified period of time.

**Other Game Decks included in the BEDC Activity:**

1. Pictures of a sunflower, the sun, and the moon/darkness. Possible hypotheses for this deck might relate to the rate of photosynthesis under various light conditions, among other examples.
2. Pictures of an individual with a headache, a bottle of Tylenol®, and a bottle of Excedrin®. One possible hypothesis for this deck might involve assessment of which drug is more effective at reducing headaches under a set of specified conditions.

It is important to note that while each of these game decks worked equally as well for the purposes of this activity (i.e., students were able to identify the pictures on the cards and develop a feasible protocol with or without the assistance of the instructor/peers), decks can easily be modified or created to accommodate for differences in course content, course level, or desired learning objectives for the activity.
Appendix 2: Sample student protocol for the BEDC activity.

Figure S2. Excerpt from a first draft of a BEDC student protocol. Students were provided with an opportunity to modify their drafts during the “conference call” portion of the activity.
Appendix 3: Biology experimental design challenge pre-/post-activity assessment.

Instructions: Please answer the following questions to the best of your ability. All responses should be recorded on the Scantron sheet provided to you in class.

1. The Scientific Method is a linear list of steps that begins with making observations and developing a hypothesis and ends with either proving or rejecting one’s hypothesis based on experimental evidence.
   a. True
   b. False*

2. Scientific discoveries are often the result of collaboration between several researchers.
   a. True*
   b. False

3. Which of the following is a testable hypothesis?
   a. Flamingos stand on one leg.
   b. Does a sunflower grow taller when exposed to 6 hours of sunlight a day or 8 hours of sunlight a day?
   c. Children who get exercise 30 min./day, 5 days a week are 3x less likely to become obese than those children who receive no exercise over the same 5-day period.*
   d. If chickens lay eggs, then do all birds lay eggs?

Consider the following experimental design (Questions 4-6):

Hypothesis: Increasing levels of nitrogen in the soil leads to retarded growth (i.e., shorter height) of Kentucky Bluegrass

Experiment:
1. Pure Kentucky Bluegrass grass seed will be planted and grown in a Greenhouse under identical conditions (e.g., same amount of water, same amount of sunlight, same temp., etc.).
2. Once the grass is one week old, nitrogen pellets will be added to the soil in varying quantities (as shown in the table below).
3. Plant height will be recorded over a 6-week period.
4. Average grass height will be calculated for each group.

Data:

<table>
<thead>
<tr>
<th>Group</th>
<th>#1 (20 pots)</th>
<th>#2 (20 pots)</th>
<th>#3 (20 pots)</th>
<th>#4 (20 pots)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>5 nitrogen pellets</td>
<td>10 nitrogen pellets</td>
<td>15 nitrogen pellets</td>
<td>20 nitrogen pellets</td>
</tr>
</tbody>
</table>
4. The dependent variable in the experiment above is…
   a. Number of nitrogen pellets added in each group
   b. Number of groups
   c. Average height of Kentucky Bluegrass plants in each group*
   d. There is no dependent variable in the above experiment

5. The independent variable in the experiment above is…
   a. Identical conditions (e.g., same amount of water, same amount of sunlight…)
   b. Number of nitrogen pellets added in each group*
   c. Average height of Kentucky Bluegrass plants in each group
   d. Six weeks

6. Based on the data, the researchers conclude that increased nitrogen pellets lead to taller Kentucky Bluegrass. Is this a valid conclusion?
   a. No, the experiment lacked a control group*
   b. No, the experiment lacked a dependent variable
   c. Yes, the data clearly shows that increasing the number of nitrogen pellets increases the height of the grass.
   d. Yes, but only to a certain point (i.e., it would be ideal if we collected more data on other treatment conditions)

Note: Correct answers are indicated by an asterisk (*).

Alternative Suggestions for Evaluating Student Learning Gains

The BEDC activity seeks to target several learning goals, including reinforcing students’ understanding of the components of scientific inquiry, the collaborative nature of scientific experimentation and discovery, and the dynamic nature of the experimental design process. Depending upon the instructor’s specific purpose(s) for implementing this activity, they may also wish to incorporate summative or formative assessments as part of the
implementation process. Such assessments might take the form of a pre-/post-activity quiz (such as the one illustrated here) and/or a one-minute paper (3) asking students to reflect on how completing the activity changed their understanding of how science is practiced. Results of these assessments could be subsequently utilized to modify the activity for future semesters or identify persistent areas of student difficulty in regard to the experimental design process.
Appendix 4: Student feedback regarding the BEDC activity.

Figure S3. Student feedback regarding the BEDC activity. Data indicate that >75% of students believed the activity enhanced their understanding of the scientific process and/or their ability to design experiments. More than 90% of the students surveyed indicated that they enjoyed the activity.