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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INTRODUCTION

The scientific method serves as a procedural framework for advancing knowledge and discoveries in a number of fields, including the natural and life sciences. Despite its essential role in these disciplines, students often perceive scientific inquiry to be a “one size fits all,” linear pursuit rather than a dynamic process (4). To address this concern, I developed the Biology Experimental Design Challenge (BEDC) game to reinforce students’ understanding of the scientific process. Specifically, the group activity focused on students’ ability to: (a) develop testable hypotheses; (b) determine suitable dependent, independent, and standardized variables for their proposed experiment; (c) interpret data to draw evidence-based claims; and (d) pose questions for future research. This process was punctuated with opportunities for each group to receive feedback from other teams regarding their experimental design, creating discussion and occasional collaboration between groups. In this paper, I present methods for implementing the activity, as well as provide evidence that demonstrates student pre-/post-activity learning gains achieved as a result of implementation of the BEDC in a first-semester introductory biology discussion course.

PROCEDURE

Creating BEDC game decks

The Biology Experimental Design Challenge activity was modeled on the Television Food Network© program Chopped, which requires contestants to create several dishes based on a series of mystery ingredients presented to them at the beginning of each round (http://www.foodnetwork.com/shows/chopped.html). Accordingly, the BEDC adaptation involved generating game decks that contained a trio of related “mystery” cards that teams of students selected at random and then utilized to collectively develop a researchable question and accompanying experimental protocol. For example, one of these game decks might contain a picture of an overweight dog, a bag of IAMS Adult Weight Control dog food, and a bag of PEDIGREE Healthy Weight dog food (Appendix 1). Students viewing this deck of cards might choose to initially test the hypothesis that the IAMS brand dog food leads to greater weight loss than the PEDIGREE brand, with future questions directed toward identifying the ingredient(s) contributing to that weight loss. As one might imagine, an affordance of this game is that students can generate numerous alternative hypotheses and future directions based on the cards in their game deck, further reinforcing the dynamic process of scientific investigation. Specific methods for implementing the activity are described below.

Implementing the BEDC activity

Prior to implementing the activity, students should be arranged into groups of four to five. At least one deck of cards is needed for each group. To ensure random selection of game decks, related series of cards should be placed into a numbered manila envelope prior to the start of the activity. If necessary, the instructor should model the activity for students. Students should then be instructed to do the following:

1. One person in each group should remove all of the playing cards from the envelope (instructor note: if you are repeating the activity more than once in a class session, ensure that students write down the number on their envelope).

2. For a period of 10 minutes, students should work collectively within their group to develop a testable hypothesis and experimental protocol that incorporates the elements pictured on the cards. Each student should record his or her thoughts on a piece of notebook paper. At a minimum, the first draft of each protocol should contain the following (these items should be written on the blackboard for reference):
   a. A testable hypothesis and accompanying prediction
   b. A clear indication of the independent, dependent, and standardized variable(s) in the experiment

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c. Simulated data (i.e., have students construct their own data) in the form of a graph or table. Figures and tables should be labeled properly.

d. Evidence-based conclusions that could be drawn from that dataset, as well as two or three questions for future research.

3. When time is called, students should immediately stop working and share their protocol with a group sitting adjacent to them. The goal of this “conference call” is for teams to discuss and exchange feedback on each other’s experiments, much like the chopping block portion of the Chopped television show but without the elimination phase. Students should spend a total of five minutes sharing ideas and an additional five minutes revising their protocol as necessary.

Depending upon the number of groups in each class, the instructor may wish to have an undergraduate or graduate teaching assistant (UTA/GTA) help facilitate the activity. This will ensure that all student questions can be addressed in a timely manner. After students have engaged in small-group discussions, 10 minutes of class time should be allocated for groups to share their designs (protocols can be displayed using a document camera, for instance; see Appendix 2) via a whole class discussion. The instructor should conclude the exercise by relating the activity back to the broader importance of the scientific process in promoting scientific advancements in the field of biology.

CONCLUSION

To determine the impact of the BEDC on student learning, the activity was implemented in an introductory biology discussion course (n = 34 students) at a mid-size Rocky Mountain Region university in the spring 2014 semester. All students enrolled in the discussion course had received lecture-based instruction on the scientific method prior to completing the activity. A pre-/posttest design (Appendix 3) was utilized, and results were analyzed using multiple pairwise comparisons with Bonferroni correction. Findings revealed significant gains in students’ overall score, as well as on subsections related to experimental design and the dynamic nature of the scientific process (Fig. 1). Data also indicated that the majority of students (>75%) benefited from the activity in a number of ways (Appendix 4).

Although the activity was conducted in a discussion environment, it is easily adaptable to lecture and laboratory contexts, with limited resources required regardless of the learning venue. Practically, instructors might especially benefit from utilizing the BEDC activity in their laboratory courses, as the primary emphasis of these experiences, particularly in recent years, is often to teach students about the process of doing science in a more authentic manner (1, 2).

FIGURE 1. Students’ pre-/posttest performance on the BEDC assessment. Individual comparisons of pre-/posttest scores for each category were all found to be significant at \( p < 0.005 \), where the “Science as a Process” category includes questions 1 and 2 of the BEDC assessment, and the “Components of Experimental Design” category includes questions 3 to 6. Error bars represent the standard deviation (%) for the corresponding data series.

SUPPLEMENTAL MATERIALS

Appendix 1: Sample card decks for the biology experimental design challenge
Appendix 2: Sample student protocol for the BEDC activity
Appendix 3: Biology experimental design challenge pre-/post-activity assessment
Appendix 4: Student feedback regarding the BEDC activity

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