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The Scientific Investigation Project – Teaching Students How Science is Done

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Effectively teaching students how science is done can only be accomplished by assisting them in actually DOING science. To that end, I have developed a semester-long project in an introductory biology laboratory course which guides students from hypothesis formation through experimental design, data analysis, and ultimately an evaluation of the validity of the hypothesis. This Scientific Investigation Project allows students to investigate factors that may be correlated with a human disease (cardiovascular disease, diabetes, or cancer) by evaluating data compiled by the CDC in their annual Behavioral Risk Factor Surveillance System (BRFSS).

Keywords: Semester project, scientific process

Introduction

A recurring premise in biology education is the need to develop scientific thinking skills in our students. While there are many mechanisms purported to accomplish this, the involvement of students in the scientific process is crucial (AAAS, 2011; NRC, 2003). A predesigned laboratory exercise can provide students with a particular skill, such as graphing, microscopy, or drawing a conclusion from a data set. Throughout the length of a laboratory course, students can accumulate many of these isolated skills. However, to encourage the development of a more complete set of skills in the process of science, students should participate in a comprehensive research project. Stated succinctly, the best way to teach students how science is done is to actually DO science.

Through the Scientific Investigation Project described here, students learn how to construct a testable hypothesis, design an effective method for data analysis, and consider the confounding factors that could influence the conclusion of their investigation. At the same time, they learn more about a human disease that may have particular interest to them.

Methods

This *Scientific Investigation Project* allows students to investigate factors that may be correlated with a human disease (cardiovascular disease, diabetes, or cancer) by evaluating data compiled by the Centers for Disease Control and Prevention in their annual Behavioral Risk Factor Surveillance System (BRFSS) (CDC, 2013). The BRFSS is an annual telephone survey of adults in more than 500,000 random U.S. households to gather information about the prevalence of various diseases, as well as information on personal behaviors and risk factors for these diseases. The complete survey data for any year can include hundreds of questions for tens of thousands of survey participants. I have extracted the data for 1000 survey participants for 70 different questions from the 2012 BRFSS data set. This is supplied as a large Excel spreadsheet to the students in the BIOL 211L Cellular and Organismal Biology laboratory course at New Mexico State University. Teams of four students use this data to evaluate a hypothesis they have developed about the correlation between a risk factor and a particular disease. The potential risk factors that may be used as independent variables include demographic information (gender, age, ethnicity, income, marital status, highest level of education),

personal behavior information (exercise habits, tobacco use, alcohol use, sleep patterns), or nutritional information (consumption of fruits, vegetables, or sugared beverages). The dependent variable for a student project must be the incidence of diabetes (type 2), cardiovascular disease, or cancer.

The project is designed to guide students by means of small weekly assignments (Table 1). These are primarily completed outside of the laboratory period. On two occasions, time is spent working on the project during the lab period. These lab periods include critical steps in the project; the proposal phase and the data analysis. A large number of the project assignments are drafts of writing assignments which are graded and later revised as another assignment. Some assignments are completed as a team, others are submitted by each individual student.

Table 1. Scientific investigation list of assignments.

Week	Project Assignment	Type of Assignment	Point Value
1	Research Teams Assigned		
2	Library Research due	Individual	5
3	Submit hypothesis Research Proposal Worksheet (in lab)	Team Team	5 10
4	Research Proposal Due	Team	5
5	Primary Literature Assignment	Individual	5
6	Revised Research Proposal Due	Team	10
7	Submit Introduction section of report	Team	5
8	Data Analysis (In laboratory)	Individual	10
9	Submit Methods section of report	Team	5
10	Submit Results section of report	Team	5
11	Submit Discussion section of report	Team	5
12	Complete Written Research Report Due	Team	5
13			
14	Thanksgiving Break		
15	Revised Research Report due Peer Grading	Team Individual	20 5
16	Final Exam Week – No Labs		Total: 100 pts

Notes for the Instructor

The variety of questions in the BRFSS data supplied to students allows them to be quite creative in the development of hypotheses. Some recent *Scientific Investigation Projects* have investigated the following hypotheses:

- "Lack of access to medical resources is a risk factor for the onset of diabetes."
- "Socioeconomic status can affect nutritional status and the frequency of cancer diagnosis."
- "There is an inverse relationship between the intake of brightly colored vegetables and the incidence of cancer."
- "There is a positive correlation between the consumption of sugared beverages and the development of type 2 diabetes."

There are many advantages to conducting this project. The primary advantage is to provide students with the opportunity to complete an experiment from initial questions about a disease, through hypothesis development and experimental design, to forming a conclusion based on the analysis of real human data. In addition, students can take ownership of the experiment, rather than simply conducting predesigned laboratory experiments. Students gain valuable skills in working with a team, the numerous opportunities to revise their assignments increases their scientific writing skills, and the data analysis exposes them to working with a very large data set. The use of the BRFSS data set is a unique opportunity for students to analyze real data from human subjects, without the difficulties that would accompany their own collection of such data.

Anonymous student surveys conducted at the end of the project have identified areas that the students find most challenging. The commitment of time, the challenge of working with a team, and the analysis of confounding factors within the data were identified as the students' greatest challenges. When asked what part of the project taught them the most about conducting scientific research, the highest proportion of students (32%) indicated that had occurred during the data analysis. Interestingly, the highest proportion of students (35%) identified data analysis as the most challenging

aspect of the project as well. The idea that the most challenging part of the project was also the part of the project in which students learned the most is reflected in numerous student comments about the project indicating that they were "proud of it", it gave them a "sense of accomplishment", and they enjoyed "taking the project from an undeveloped hypothesis to a full out lab report".

The *Scientific Investigation Project* continues to evolve based on feedback from students and graduate teaching assistants. The primary literature assignment is a new addition to the project, intended to guide students in their selection of quality, relevant resources. Students indicated that they would benefit from access to examples of similar written reports, either from peer-reviewed journals or from previous students in this course. At this point I have only provided them with a peer-reviewed article that hopefully will provide an example of the type of analyses they should conduct. The use of an enormous preexisting data set will allow me to change the data provided to students from one year to the next, and increase the variety of hypotheses that can be tested. The Scientific Investigation Project will continue to be an effective mechanism for teaching students how science is done.

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About the Author

Amy Marion earned her BS in Biology at Marywood University in Scranton, PA and her PhD in Botany at the University of Vermont. Since 2001 she has served as the Laboratory Coordinator in the Biology Department at NMSU, focusing on introductory laboratory courses for majors and non-majors.Instructor Materials

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