The Scientific Method and Basic Microbiology

Abstract

In this activity students are to create and test a hypothesis about the effectiveness of house cleaners using the scientific method and analyze their data using free web based statistical analysis software. Students begin by participating in a class discussion about the scientific method, hypothesis generating and the importance of using statistics to determine if data is statistically significant. Students then learn basic microbiology background information including sterile technique and zone of inhibition. Next, the students design an experiment testing the effectiveness of conventional and organic household cleaners. Students will then put the class data into an ANOVA using Vassar stats to determine statistical significance. Students will use the data from the Tukey test to determine where the statistical significance is located in the data. Students will use the information to write a data driven conclusion. Finally, students will re-analyze the information from the beginning class discussion to make conclusions about the potential of bias in the statistics presented to us on a daily basis.

Overview and Purpose

Students do not understand statistics and take any number presented to them at face value. Teaching students about the role of statistics in science helps to empower them with knowledge to write data driven conclusions and feel confident in questioning the validity of any experiment. This allows students to become critical of any scientific fact presented to them promoting scientific thought processes in their daily lives.

This activity is designed in two parts to promote the application and understanding of what is needed in every experiment to make a statistically significant conclusion. The procedure begins by bringing in articles or advertisements that contain any form of statistics. Students participate in a discussion about what the statics mean and the assumed hypotheses begin tested. Students then cover information needed to understand the scientific method, hypothesis generating and basic statistical analysis. The second part of the procedure asks students to design an experiment testing the effectiveness of conventional and "homemade" household cleaners on killing common kitchen bacteria (*Salmonella*). Students use the ANOVA function on Vassar stats to find their P value and post hoc (Tukey test) information and are expected to write a proper conclusion using their statistics as direct support. Students will then go back and look at the ads/articles from the beginning of the lesson to explain why we should question the validity of the statements made. Finally, the experiences gathered from this lab can be used to analyze the data from every lab activity that follows throughout the year. As a result, students will have overall increased science literacy skills and will be better prepared for college level science expectations.

How is it innovative?

Many students are satisfied with saying that an experimental hypothesis is supported if the data collected for the experimental groups were different. According to the students, any difference, no matter how small, indicates support or rejection of a hypothesis.

However, this is not how science in the real world is completed nor does it promote critical analysis of the data (including acknowledgement of possible outliers).
The innovation of this lesson plan lies within its simplicity. Students already have an assumption about what the conclusion of the experiment will show but often are surprised when they see that usually the class data does not indicate a significant difference among the cleaners tested. By doing this experiment at the start of the year students actually get to see how their personal biases could have caused them to make improper conclusions about the data. As a result of this experience, students question every piece of data they collect in subsequent experiments.

Description of Unit
This activity serves as the middle activity of the first unit covered when students return from summer break. We begin the unit by reviewing the metric system through the use of the metric system Olympics and conversion practice. We then cover the creation of graphs by using the measurements we obtained from the Olympic Games. The students then are briefly introduced to basic microbiology including sterile technique and zone of inhibition. Once students have had sufficient practice with these concepts and techniques we begin covering scientific method, hypothesis generating and statistical analysis through the use of this lesson plan. Finally, students are challenged to use the skills they gained from covering this unit in a case study by Conrad Toepfer called "Disappearing Marine Iguanas: A Case of Population Collapse". In this study the students are expected to use a variety of data (graphs, statistics, maps, observations) to make a data driven conclusion about the cause(s) of the population change. By the end of the unit I expect my students to know how to properly use the metric system, interpret data in multiple formats (graphs, tables), create a testable hypothesis using the null / alternative hypothesis method, use sterile technique and properly use statistical analysis to accept / reject the hypothesis.

Kentucky Academic Expectations for Science

The Kentucky Academic Expectations define what students should know and be able to do upon graduation from high school.

Goal 2: Students shall develop their abilities to apply core concepts and principles from mathematics, the sciences, the arts, the humanities, social studies, practical living studies, and vocational studies to what they will encounter throughout their lives.

2.1 Students understand scientific ways of thinking and working and use those methods to solve real-life problems

2.2 Students identify, analyze, and use patterns such as cycles and trends to understand past and present events and predict possible future events.

This lesson plan also meets the requirements of AP Science classes which require that students understand how to use data analysis (including statistics) to interpret data collects in lab investigations.

ACT Standards
Interpretation of data: Analyze given information when presented with new complex information

Scientific Investigation: Understand the methods and tools used in a moderately complex experiment

Evaluation of models, inferences and experimental results: Determine whether given information supports or contradicts a hypothesis or conclusion and why

Objectives
Students will be able to

1. Create a testable hypothesis using the null/alternative hypothesis method.
2. Properly use statistical analysis programs to analyze data collected
3. Appropriately interpret and apply statistical data
4. Identify and explain outliers and potential bias in scientific experiments
5. Understand and use basic microbiology terms and techniques

Assessment
Students will be assessed on their understanding of the lesson through their written answers to the questions within the lab. Students will also be required to write out a lab report based on their findings. Furthermore, students will take a test at the end of the unit where they will have to interpret statistical analysis information to determine if a hypothesis should be accepted or rejected. Finally, the skills gained in the activity will be used in every lab activity for the rest of the year in order to properly analyze the data.

Materials
6 agar plates per group
Salmonella inoculating starter (NOTE – can just swab raw chicken if needed)
Inoculating loops
Sterile swabs
Alcohol burners for sterile technique
Filter paper hole punches (5 per plate)
Water
Household cleaners (various types)
Homemade household cleaners
Tweezers
Internet access

Procedure

1. Inoculate 6 agar plates per group with *Salmonella* and allow the plates to incubate over the weekend.

2. Check the plates on Monday and make sure that each plate is covered in a lawn of bacteria.
3. On 2 plates place 5 filter discs that have been exposed to distilled water.
4. On 2 plates place 5 filter discs that have been exposed to a conventional household cleaner (e.g. Lysol).
5. On 2 plates place 5 filter discs that have been exposed to a “homemade” household cleaner (e.g. baking soda).
6. Allow the plates to incubate for 1-2 days.
7. Measure the zone of inhibition around each of the discs on each plate and record the data.
8. Put the data into the Vassar-stats ANOVA function and determine the p-value.
9. Use the post-hoc (Tukey test) function to determine where statistical significance is located.
10. Soak the plates in 20% bleach water before disposing of them.

Activities outside the classroom

Students are required to look up information about common household cleaners and homemade household cleaners for homework. They are also required to bring in various advertisements with some form of statistics on them for the preliminary discussion about statistics and hypothesis testing. After data collection is complete the students are required to create a lab report based on their findings. Finally, students are challenged to use the skills they gained from covering this unit in a case study by Conrad Toepfer called "Disappearing Marine Iguanas: A Case of Population Collapse". In this study the students are expected to use a variety of data (graphs, statistics, maps, observations) to make a data driven conclusion about the cause(s) of the population change.

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