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TxCETP Course Component:

How Sweet It Is!! Conducting a Controlled Experiment

Introduction

Background Story

Harvey (Harv to his friends) A. Sweettooth, owner of the Sweettooth Candy Factory, has a fine line of hard candies. Recently, Harv received a letter from a long time client, a Ms. Susie Saccharin, complaining that the candies in his assorted hard candies line did not all dissolve at the same rate—**and that the fastest dissolving of the candies were over represented in the bags of candy she had checked.** Harv has called on you to investigate Ms. Saccharin's complaints.

Note—Bolded text may be omitted.

Activities

Teaching Questions:

1. What are Ms. Saccharin's complaints? (Brainstorm)
2. Can you reword the complaints in the form of questions that you can investigate?
3. Based on your question, write a hypothesis that would provide a causal explanation in answer to your question.
4. Design a controlled experiment to test your hypothesis.
5. Write a report describing your experiment and results.

Teachers:

Conducting a Controlled Experiment

Hand out the background story and include a baggie for each group of students with a representative “sample” of candies of the kind that Ms. Saccharin had complained about.

Materials

Option 1: If you are only investigating the complaint about how fast some candies dissolve, each baggie will only need to include 1 of each shape in the sample. You might also include instructions on measuring surface area and volume. You will need to provide balances, rulers/and or tape measures. Each student or group of students should receive hard candies in the following shapes (as available)—spheres (balls), discs, rods, squares, and barrels. If possible, the candies should be all the same flavor (However, flavor can be a variable which they choose to test). The candies should be individually wrapped, hard candies. Most of these should be readily available at major supermarket chains or discount stores. Diabetic students can be accommodated by providing sugar-free substitutes. If you wish, you can add the variable “sugar-free” to the list.

Option 2: Instead of actual candies, you provide students with pictures of candies. Pictures of several different types of candies are provided. You could also provide students with counts of the different types of candies in a “random” sample of bags. The activities for this option are Parts A, B, and C only (see below).

Option 3: If you are including the complaint about over representation of the fastest dissolving candies, you have two options: A) before placing the candies in bags, mix them thoroughly, then draw random samples of at least 30 pieces of candy in each sample. This option should indicate that there is no over representation of any one type of candy. B) “Doctor” your samples so that the candy that dissolves the fastest (the one with the greatest SA/V ratio) is included more often (2-3X more) than the other candies.

Part A. Defining the problem.

Teaching Questions:

1. What are Ms. Saccharin’s complaints? (Brainstorm)

Formative Assessment:

What observation(s) is/are Ms. Saccharin using to base her complaint on?

2. Can you reword the complaints in the form of questions that you can investigate? (Brainstorm—List questions on the board) [Sample questions: Do all the candies in the sample dissolve at the same rate? Are there the same numbers of each type of candy in the bag?] Try to

encourage more ideas—then come back and ask the students to eliminate ones that could not be easily tested or are not relevant. Steer the discussion to pare down the list to one or two major questions. “Do all the candies dissolve at the same rate?” or “What factors affect the rate at which candies dissolve?” You may end the discussion by saying, “Those are some interesting questions but let’s investigate this one” and provide the question of your choice.

Part B. Possible explanations.

Teaching Questions:

1. Based on your question, write a hypothesis that would provide a causal explanation in answer to your question.

Mini-teach: Testable Hypothesis. A good hypothesis has the following characteristics:

1. Based on observations—why would Ms. Saccharin think that the candies didn’t all dissolve at the same rate?
2. Provides a causal explanation—should answer the question why or how. “The candies don’t dissolve at the same rate *because* they are different shapes.” Because answers the question “Why”.
3. Testable AND falsifiable—doesn’t rely on supernatural or unobservable explanations.
4. Generates predictions—A prediction is what you think the outcome of the experiment should be. You should be able to explain what your data will look like if the hypothesis is supported—and if it is not. “If the candies don’t dissolve at the same rate because they are different shapes, then those with a greater volume should dissolve more slowly.” Predictions should be directional—more or less slowly or faster or....
5. They are supported or not supported. One of the most overused (and incorrectly used) terms in science is the word “proven”. We often see scientists in the media claim to have “proven” their theory or hypothesis. Proof means it is a 100% absolute certainty that their explanation for the observed phenomenon is correct. There are very few absolutes—unless you are 100% certain that you have accounted for all the variables, you cannot say you have proven—or disproven—your hypothesis.

Formative Assessment:

Working in groups, have the students write their hypotheses in large print (on poster sized paper if possible). Have each group share their ideas and produce a class list.

OR

Brainstorm with the whole class to produce a list. (This choice is less time consuming).

Either way you should generate lists similar to the following:

Sample Brainstorm List: consistency, size, flavor, shape, the person eating the candy, etc.

Part C.

Once the lists are completed, as a whole class question, ask “Which of these could we test right now with the materials you have in front of you?”

You can allow the students to choose a variable to test or you can opt to choose one for them. Either way, you will want them to write a causal explanation (hypothesis) for the variable they (or you) choose.

After the variable has been selected and a hypothesis written to be tested by the entire class, allow the students to return to their groups and design an experiment to test the hypothesis. You can provide a brief description of what is involved in a controlled experiment, but try to provide as few terms and overt directions as possible.

While they are working in groups, circulate around the room listening to their ideas. Ask questions to steer their thinking toward including all the elements of a controlled experiment—provide information, definitions, corrections as needed, but allow students to figure things out for themselves as much as possible.

Each group should be asked:

1. What are you going to do? Follow up their answers by asking specific questions about their methods e.g. “How will you know if it is (variable) that is causing the candy to dissolve faster?”
2. How will you know if your hypothesis is supported or not? Their answers to this question should provide a directional prediction of experimental results e.g., “The candies with the greatest surface area to volume ratio will dissolve the fastest”.

At the end of this exercise, they should have designed an experiment with the following elements:

1. An Experimental Group—these subjects will be exposed to the experimental variable

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2. A Control Group—these subjects should be treated exactly the same as the experimental group EXCEPT for the one variable that you are testing.

NOTE: Because of the nature of this experiment, the control may be difficult to identify. This is a good place for the whole class to discuss the purpose of control groups and their importance. (Why do we need a control group?) It is perfectly acceptable for students to act as their own “controls” in this experiment (Repeated Measures design).

3. Students should explicitly identify the variable being manipulated and variables held constant. It may be necessary to define the terms **variable** and **constant** for them.

- t Methods should be clear enough that if they were to switch with another group, the experiment could be conducted the same way.
- t Assumptions should be listed e.g. “on average, each person should have the same rate of dissolving candies of the same rate”
- t What will their subjects be told?
 - i This is a good place to discuss biases—if the subject thinks that the rod-shaped candies will disappear the fastest s/he might subconsciously suck harder on that candy than on the others
- t What will you collect for data? What are you writing down?
- t What will you compare your data to for analysis?
 - i This is a good place to discuss statistics, normal distributions (Bell curve) etc.
- t Predictions: If your hypothesis is correct, what will your data look like when you graph it? What if your hypothesis is incorrect? Make sure that the whole group agrees on what to expect.
- t These elements can be combined using the “If, and, then” format (Lawson, 1995). For example: IF the shape of the candy influences how fast it dissolves because different shapes have different SA/V (statement of hypothesis) AND we measure the amount of time it takes several different people to completely dissolve each different shape of candy (brief description of experiment) THEN the candy with the largest SA/V ratio will dissolve the fastest.
- t Results will vary depending on which candies you are able to obtain. However, if size and consistency are fairly even, the candies with the largest surface area/volume ratio should dissolve the fastest. If you really want to stack the deck toward this outcome, you can include “donut”-shaped candies that should provide a greater surface area.
- t Standard to measure results against—How do we know if our results are due to the difference in SA/V ratio or just random chance?

Part D. (Option 1 only)

If time permits, have the students conduct the experiments they have designed in individual groups. If pressed for time, agree on a whole class experimental design and conduct the experiment as a whole class. Collate the results—if in groups, encourage students to share and compare their results with those of other groups. Point out that this is a part of the “Science Process” as well.

Part E. (Option 1 only)

Analyzing and Interpreting Results

Summative Assessment: Write a report describing your experiment and results.

You will need to provide a detailed description of the report format (Lawson 1995 and Russell and French 2002).

(Option 3 only)

Summative Assessment: Graph the distribution of candies found in your sample. Compare the distribution to the results of your experiment. Is Ms. Saccharin’s complaint concerning the number of fastest dissolving candies valid? Explain.

Summative Assessment (MC Questions to be added later as Interactive tests)

References

Lawson, Anton. 1995. Studying for Biology. HarperCollins CollegePublishers.
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