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| **Title: Experimental Design and Hypothesis Testing in the Real world.** |
| **Learning goals**:   1. Incorporate new information into an existing experimental hypothesis. 2. Understand the role of limited available resources (including time, money, and technology) in experimental design and scientific work. 3. Recognizing that part of the scientific process involves challenging past experimental results and retesting hypothesis with advancement in technology, resources and knowledge. 4. Evaluate Scientific Claim not as absolute truth, but as current best understanding based on available information. |
| **Instructions for the faculty**:  **Buying Candy:**  This unit requires the use of a limited resource, in this case natural-colored candy-coated chocolate (as opposed to M&Ms, which are artificially flavored). There are a few available ways to get this resource, but it is best to plan ahead. In all cases, buy only one bag or two (total of about 100-200 candy, (7ounces=210 candy)  Sunspire Sundrops is a natural color alternative to M&Ms, and can be found in a few stores about 5-8 miles away from Annandale-on-Hudson. <http://www.sunspire.com/find-a-store>  If available, you can find Smarties, a European form of M&M, from Amazon or in many city grocery stores with imported candy. You will need 3 tubes of 38g. However, you can’t get it from Amazon directly, because…  <https://www.techdirt.com/articles/20100609/0126569748.shtml>  Alternatively, there is Unreal Candy, which is distributed in some CVS’, Whole Foods or online. <http://getunreal.com/products/candy-coated-milk-chocolates> Find a store here. <http://getunreal.com/pages/store-locator>  This is a teaching subunit of the **Van Halen and Brown M&Ms** teachable unit. In the base teachable unit, students were encouraged to design and conduct an experiment and interpret the results. Here, we expand this example, incorporating aspects of Research that Scientists have to take into account in the real world. This teaching unit also shows through both literature review and practice, how Scientific Progress occurs with advancing understanding and technology.  This module can lead to further analysis of review papers in different fields. This module can also lead to a discussion on what is valid criticism of Scientific claims, and what is not.  ASSUMED PRIOR KNOWLEDGE: Students should already know the difference between primary and secondary/review literature. It would also be useful to teach students how to read secondary literature in a field which they are unfamiliar with.  FACULTY SPECIALIZED KNOWLEDGE. Personal anecdotes of having to deal with limited resources during experimental planning, or using current technology to dispute previously published results, would be useful while teaching this course. |
| **Intended outcomes**:  After this activity, students should recognize that oftentimes, research in science requires compromise between experiments scientists would like to do, vs those that are possible. They should also recognize that these shortcomings can and are oftentimes corrected in the future, with advancement in interest, resources and technology. In fact, this is a ‘feature’ of Science, not a ‘fault’. |
| **Assessment**: Students will be required to read and summarize parts of a review paper, showing understanding of changes in different experimental setups, and why these different experiments might yield different results. |
| **Activities**:   1. This activity starts after students have completed the teaching unit, brown M&M and Van Halen. Upon concluding that the null hypothesis is correct, that Brown M&Ms taste the same as other M&Ms, start activity by asking students if they know where food coloring is made of? 2. Inform students that artificial food coloring are a petroleum byproduct. These colorings started to be used widely and became popular in the 1960s. David Lee Roth, and other members of the band, however, grew up before the 1960s. 3. At that time, they would have been eating M&Ms made with different, possibly natural, food coloring. Ask students to spend a minute thinking and writing about how this would change their interpretation of their results? How would they then modify their hypothesis in order to take into account this new information? Use Think-Pair-Share here for a few minutes in order to allow students a chance to practice the skill of hypothesis formation they learned earlier. (Answer: That Van Halen might have gotten used to eating natural colored M&Ms as a child, and with that candy, there might be a taste difference between brown and other colors). 4. After listening to their ideas, talk about how oftentimes, scientists have to take into account previously unknown information in revamping own hypothesis in a more general way. Include personal anecdote if you do research, or information from your field of expertise. 5. Mention Feingold’s study (summary can be found in Student\_ReviewADHDAFC, or primary Student\_PrimaryArtificialFoodColoring). Tell students that his work suggests a link between ADHD and Artificial Food Coloring. Assign the reading Student\_ReviewADHDAFC, with focus on sections describing EarlyWork on food additives/dyes and ADHD, and Recent research on synthetic dyes and ADHD. Assign a close reading of these experiments as homework, and a two page summary, with prompt listed on Student\_Shortpaper. 6. For class, explain that in Europe, partly in response to Feingold’s study, the use of artificial food coloring in children’s candy was banned in 1994. Furthermore, even in the States, there are alternatives to M&Ms that use natural food coloring. 7. Bring out the natural colored alternative. Give out the handout for the new experiment (Student\_NatFC). Point out that unlike the almost limitless M&Ms, here the number of available candy/resources is much more limited (because it is so much more expensive.) Point out how this is similar to the decisions scientists face every day, when they have to design the best experiment based on the resources they have available. Personal anecdote is good here too. 8. Ask students to design a new hypothesis and new experiment in order to use this resource. Remind students that they are one step removed from the original observation (of Van Halen and brown M&Ms) and therefore are not beholden to that original experiment (nor would it be possible with amount of resources available. Sample answer found in Faculty\_NatFC\_ANSWERKEY but it’s important here to look for creative ideas, and point out possible shortcomings. All these experiments will have shortcomings, but it’s about the best possible experiment when faced with limitations. If using the StatSignificance subunit, important to ask if their experiment has statistical significance. Do calculate on board. 9. Allow students to conduct experiments and collect data. 10. Draw Conclusions and finish with discussion on how the new experiment relates to the first experiment. Explain that science is oftentimes a series of experiments, one after the other, that tries to clarify or change the conclusions of the experiment before. It’s partly how scientific progress occurs. Tonight, they will read a series of experiments on ADHD and food coloring that followed Feingold’s original work. Ask that they try to see how each subsequent work/publication built on what was found before, how each study attempts to answer the shortcomings of the previous study. 11. Next Class section. Go over the experiments in the review. Walk students through some of the experiments. Alternatively, you can divide up the class into groups, and do a jigsaw, where each group focuses on one set of experiments assigned, then share what they learned with rest of class. 12. Ask for a final conclusion. Are students convinced of the effects of food coloring on behavior and link to ADHD? What would be the best experiment to conclude one way or the other? (Concept of necessary and sufficient). Answer is in botoom of Faculty\_NatFC\_ANSWERKEY 13. This class should end with a discussion that compares and contrasts valid vs. invalid criticism of scientific results. Clearly scientists criticize one another’s results all the time. How is this different from non-scientific criticism? Why are some forms of criticisms valid, and others not? Do intentions matter? |