ATLANTA SCIENCE FESTIVAL

Lesson Title	Engineering: Pill Coatings
Grade Band	High School Chemistry/Physical Science
Submitted by	Donna Barrett, Metro RESA

Georgia Performance Standards:

SC5. Students will understand that the rate at which a chemical reaction occurs can be affected by changing concentration, temperature, or pressure and the addition of a catalyst.
a. Demonstrate the effects of changing concentration, temperature, and pressure on chemical reactions.

SCSh3. Students will identify and investigate problems scientifically.
a. Suggest reasonable hypotheses for identified problems.
b. Develop procedures for solving scientific problems.
c. Collect, organize and record appropriate data.

Safety Considerations:

Student should wear safety goggles during the activity. The activity materials have the potential to be extremely messy, so emphasize cleanliness and keep cleaning materials nearby. Consider laying down newspaper on and around the desks as protection from spills.

Materials & Time Required:

Materials – clear diet soda, markers, flour, corn starch, sugar, vegetable oil, paper plates, plastic spoons, color coated candies - *Each group needs:*

- 60 mL (1/4 cup) flour
- 30 mL (1/8 cup) corn starch
- 60 mL (1/4 cup) sugar
- 30 mL (1/8 cup) vegetable oil
- 1 paper plate
- 4 small paper or plastic bowls
- 1 clear plastic cup
- 1 small plastic spoon
- 2 pieces of color-coated candy

Lesson Logistics (for teacher):

Source of Activity:
https://www.teachengineering.org/view_activity.php?url=collection/cub_/activities/cub_biomed/cub_biomed_lesson05_activity1.xml

Similar Activity – Digestion Simulation:
https://www.teachengineering.org/view_lesson.php?url=collection/cub_/lessons/cub_human/cub_human_lesson04.xml

Troubleshooting Tips

To make very sticky concoctions more workable, add extra flour or corn starch.
To prevent students from making a super-thick coating, set a limit on the maximum thickness permitted. Constraints like this are typical in real-world engineering design projects.

Background (Additional Background Below)

The protective coatings placed around pills are almost as important in the treatment of illnesses as the chemicals included in the pills. Pill coatings fulfill a variety of purposes, depending on the type of medication they are encasing. In some circumstances, the coating is used to extend the useful life of the drug by protecting it from exposure to temperature, moisture or light. The coating also keeps pills from being cracked or broken during handling. Some protective coatings mask the taste of the chemicals, making the pill easier to swallow. In other cases, the coating acts as a protective barrier, keeping the pills from being dissolved by highly-acidic stomach conditions or extremely-basic small intestine conditions so they dissolve in other target locations, where they are more effective. Stomach absorption must be prevented in cases in which the medication is a stomach irritant. Other situations require that the drug be dissolved in the stomach, so the covering is formulated to dissolve quickly.

Pill coatings are used for more practical purposes as well. Some coatings can be printed on by special printers, aiding in the labeling process. When pills are labeled by indentations, the coating must be thin enough to form to the shape of the pill and not mar the labeling. Thinner, less bulky coatings are preferred as they are helpful in decreasing the cost of packaging and shipping. Pills' coatings must be non-sticky to prevent them from sticking together during shipment and storage. Incorporating colors and patterns into the surface coatings is useful for marketing efforts. Engineers are involved in developing and testing chemicals for coatings as well as designing the manufacturing systems required to mass produce uniformly-coated pills.

- Biomedical engineers use experiments to discover how various chemical substances react in the human body, for example, the absorption of medication and how the body breaks down the outer coatings of pills and capsules. To test new medicines, scientists use solutions with chemical compositions similar to the environments found in the human body to model various body reactions. Engineers also create all sorts of devices and tools used in experiments, and creative medicine delivery materials and equipment, including syringes and patches, and even the factories for making different types of pills and bottling liquids.

More in-depth teacher background (also below) can be found at: https://www.teachengineering.org/collection/cub_/activities/cub_biomed/cub_biomed_lesson05_activity1_background.pdf

Opening: ENGAGE

The Dilemma

- Sarah is a fifth-grade student with an extremely sensitive stomach that is irritated by certain foods and many medications. Sarah recently came down with an illness that caused her to have a high fever, among other symptoms. Her mother wants to help Sarah fight the fever by giving her some aspirin, but she is afraid that the medicine might make Sarah's stomach hurt. Can you think of some ways you might be able to help Sarah?
- Many medicines help our bodies fight sicknesses and diseases, but can also make our stomachs hurt. Can anyone tell me where the stomach is in the digestive system and what it does?

An Engineering Solution

- To prevent this stomach pain while still allowing the medication to get into our bodies, engineers and pharmacists have developed pill coatings that do not dissolve until after they have passed through our stomachs. These specially coated pills are called "enteric-coated" pills or tablets.

- Today, we are going to help Sarah by acting as engineers and developing our own "enteric" coating. We will create a recipe for our coating, and then test it by observing its effectiveness in protecting a piece of candy placed in an environment that simulates the environment found in our stomachs. Before we get started, why is it better to test the pill in a simulated environment rather than testing it on a human? Then, just like engineers, we will analyze our coating and make suggestions for improvements to our design

Work Session: EXPLORE/EXPLAIN

Explore (see procedure below and refer to the TE website "Protect that Pill"**:**

- Each group needs:
- 60 mL (1/4 cup) flour
- 30 mL (1/8 cup) corn starch
- 60 mL (1/4 cup) sugar
- 30 mL (1/8 cup) vegetable oil
- 1 paper plate
- 1 small plastic spoon
- 2 pieces of color-coated candy

Engineering Information

Flour and cornstarch are thickening agents with fairly similar properties. They also improve the workability of the overall mixture.

Sugar thickens the mixture to some extent and makes the texture grainier, but can also make it less soluble when used in the right proportion, thereby improving its performance as a protective coating.

Engineering Challenge

- Decide how much of each ingredient should be used for the coatings.
- This is the recipe, SEE document on the worksheet.
- Use your recipe to begin mixing the coatings on paper plates.
- If more of a certain ingredient is called for, carefully measure it and add it into the mixture, remembering to make the changes to the recipe on the worksheet.

Testing

- Bring the test coatings to the testing table.
- Place coated pill in the acid solution.
- Time the rate of dissolution.
- Observe other groups.

Closing: EXTEND/EVALUATE	**Extend: Improving the Engineering Design** • Using what was learned from analyzing the testing results and original recipes, write down a new and improved coating recipe. • Follow the new recipe, mix up a new coating batch. • Do not make changes to the recipe. **Evaluate: Post Assessment** • Which pill form works the fastest? Why? • Which form of medicine (pill, liquid or injection/shot) works the fastest? Why· • Describe three suggestions of what you might do to get medicine to work more quickly. Provide explanations of why you think they may work.

Documentation of Resources:

Teach Engineering: Protect that Pill
https://www.teachengineering.org/view_activity.php?url=collection/cub_/activities/cub_biomed/cub_biomed_lesson05_activity1.xml

Procedure

1. Divide the class into groups of two or three students each.
2. Pass out worksheets and materials to each group (see Figure 1)

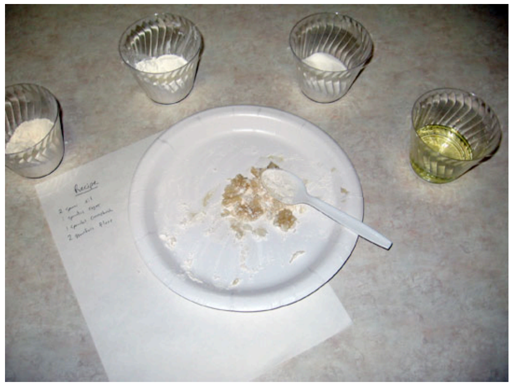

Figure 1

3. Discuss with the class the different properties of each ingredient. Oil helps the dry ingredients stick together, helps make the mixture less sticky, and makes the coating less soluble. Flour and cornstarch are thickening agents with fairly similar properties. They also improve the workability of the overall mixture. Sugar thickens the mixture to some extent and makes the texture grainier, but can also make it less soluble when used in the right proportion, thereby improving its performance as a protective coating.
4. Before any mixing is done, have student teams decide amongst themselves how much of each ingredient (in spoonfuls) they think they want in their coatings. These become their recipes, which they document on their worksheets.
5. Following their recipes, direct students to begin mixing their coatings on paper plates (see Figure 1). If a team feels that more of a certain ingredient is called for, have them carefully measure it and add it into the mixture, remembering to make the changes to the recipe on their worksheets.
6. When a group has finished creating their coating mixture and recipe, have them apply the coating to a piece of candy (see Figure 2). Encourage students to make a thin and sleek design so the pill is easy to swallow, inexpensive to ship, and requires less packaging.

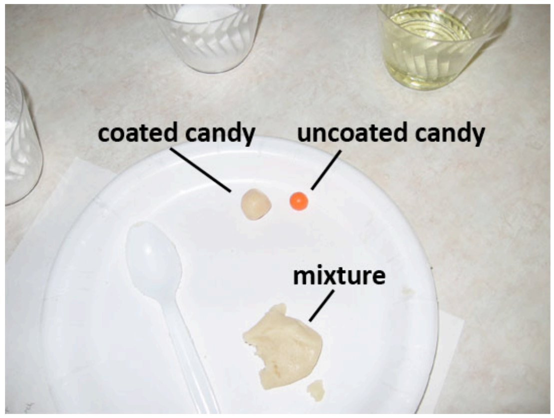

Figure 2

7. When all of the groups are finished, have a representative from each bring their coated candy to the front of the class. For each team, fill a plastic glass half full with clear soda, plus one extra cup of clear soda for an uncoated piece of candy (so students can see their coatings' effect on the dissolving rate of the candy). Label the cups with a marker so each group's cup can be easily identified.
8. With the timer ready, and at the same time, have students drop their coated candies into their cups of clear soda, while the teacher drops an uncoated candy into its cup of clear soda as a control (see Figure 3).

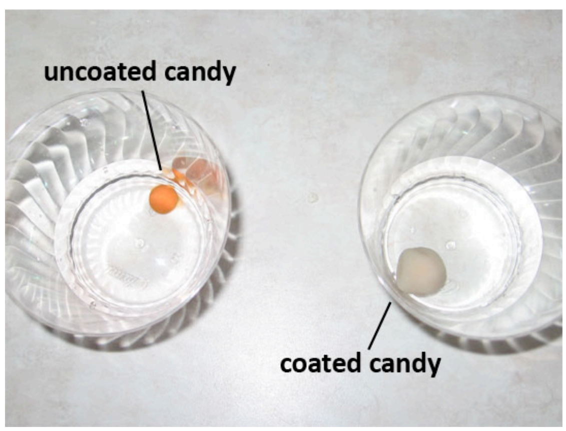

Figure 3: At the beginning of the test

9. Allow the candy to sit in the soda for 10 minutes (see Figure 4). After several minutes, if the coatings do not look like they are dissolving, have one student from each group stir their coated candy in its soda cup until the 10 minutes is over. Ask students: How does this step simulates a pill going through the human digestive tract? (Answer: This simulates the acidic environment of the stomach, as well as its churning and agitating movement.) Why is it better to test the pill in a simulated environment rather than testing it on a human? (Possible answers: The coating could fail and make the person's stomach hurt, it is easier to observe how the pill dissolves in the simulated environment, etc.).

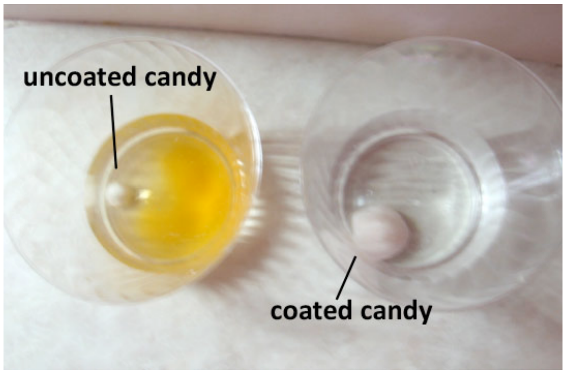

Figure 4: After 8 minutes

10. While waiting, keep students busy with another class activity or by having them draw ads that describe the benefits of their pill coatings.
11. After 10 minutes have passed, have students remove their pieces of coated candy from the soda-filled cups (see Figure 5). As a class, make observations about which coating did the best job of protecting the candy "pill" and compare the coating recipes for each group to see what did and did not work. How did the coatings perform, compared to the uncoated control "pill," and compared to the various team recipes?

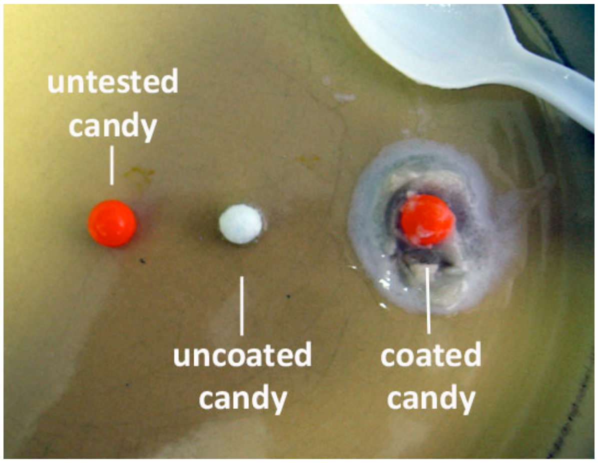

Figure 5

12. Have students calculate on their worksheets the fractions represented by each ingredient in their recipes. Compare recipes among teams, and discuss as a class, as described in the Assessment section. What are the relationships between performance and proportion of certain ingredients? What are the advantages and disadvantages of using certain materials?

13. Using what they learned from analyzing the testing results and original recipes, direct each group to write down a new and improved coating recipe.

14. Following their new recipes, have each team mix up a new coating batch. Do not allow them to make changes to their recipes during this stage.
15. Repeat the same procedure for coating and testing, and then compare the results again as a class. What improvements were made?
16. Conclude by reflecting on the activity in terms of the universal steps of the engineering design process: Ask, Imagine, Plan, Create and Improve, as described in the Assessment section. These are the steps engineers go through in designing new products and processes.

Recipe and Fraction Worksheet

Recipe #1		
	Number of Spoonfuls	Fraction
oil		
sugar		
flour		
corn starch		
Total		

Recipe #2		
	Number of Spoonfuls	Fraction
oil		
sugar		
flour		
corn starch		
Total		

$$\text{Fraction} = \frac{\text{Number of spoonfuls of ingredient}}{\text{Total number of spoonfuls}}$$

Teacher Background: Protective Pill Coatings

The protective coatings placed around pills are almost as important in the treatment of illnesses as the chemicals included in the pills. Pill coatings fulfill a variety of purposes, depending on the type of medication they are encasing. In some circumstances, the coating is used to extend the useful life of the drug by protecting it from exposure to temperature, moisture or light. The coating also keeps pills from being cracked or broken during handling. Some protective coatings mask the taste of the chemicals, making the pill easier to swallow. In other cases, the coating acts as a protective barrier, keeping the pills from being dissolved by highly-acidic stomach conditions or extremely-basic small intestine conditions so they dissolve in other target locations, where they are more effective. Stomach absorption must be prevented in cases in which the medication is a stomach irritant. Other situations require that the drug be dissolved in the stomach, so the covering is formulated to dissolve quickly.

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Historically, sugar coating was the most popular pill coating. Due to the numerous drawbacks of sugar coating, modern coatings often have a polymer and polysaccharide base and include additives such as pigments and plasticizers. Incidentally, one coating that is used for candies as well as medications is confectioner's glaze or pharmaceutical glaze, which is used as an enteric coating in the pharmaceutical world and as a glossy finish and protective coating on both candy and medications. The primary ingredient in this coating is "shellac," an excretion from laccifer lacca or kerria lacca, a bug of the lac family. This excretion is harvested from trees and processed and refined. Another natural coating used on both candies and pills is carnauba wax, a product derived from the leaves of the carnauba palm.

Sources for images to show students:
See a photograph of shellac excretions at the Spectroscopy NOW website:
www.spectroscopynow.com/ftp_images/2Lac2.jpg
See a photograph of unprocessed shellac at the Lexportex (India) Pvt. Ltd. website:
www.indianshellac.com/pics/pic2.jpg
See a photograph of a supercell tablet coater at the GEA Process Engineering Inc. website:
http://www.niroinc.com/images/pharma_systems/supercell_tablet_coater.jpg

Source: Biomedical Engineering and the Human Body: Lesson 5, Protect That Pill Activity
— Protective Pill Coatings Teacher Background Sheet