BASIS Lesson Plan

Lesson Name: Protect that Pill!

Grade Level Connection(s)

Next Generation Science Standards: Grades 3-5, Engineering
Grade 4, Life Science (4-LS1)
FOSS NGSS Edition: Grade 5, Life Science (Living Systems)

**Note to teachers: Detailed standards connections can be found at the end of this lesson plan.*

This lesson has been adapted from a lesson called Protect That Pill, from the Integrated Teaching and Learning Program, College of Engineering, U. Colorado Boulder.

Teaser/Overview

Have you ever been sick and needed some medicine? Was that medicine a liquid or was it contained in a pill? If you have ever needed to swallow a pill, you can thank engineers for making it a little easier! In this fun (and a little bit messy) hands-on lesson, students work collaboratively to solve an engineering challenge about medicine. Students will learn about the coating that protects the chemical components of a pill in order for it to work correctly. Then students will work together to engineer their own protective coating for a "pill" (a piece of candy) and place it into a container that simulates our stomach acid to see if the coating can stop it from dissolving right away!

Lesson Objectives

- Students will be able to describe and employ the engineering design process.
- Students will be able to describe how simulation is used to test the body's reaction to medication.
- Students will be able to explain some of the ways that engineers can help people stay healthy.
- Students will reinforce their understanding of different parts of the digestive system.

Vocabulary Words

- **Dissolve**: When a solid is incorporated into/becomes part of a liquid (e.g. salt dissolves into water to form salt water)

- **Bioengineering**: The application of engineering principles to biology or medicine
- **Soluble**: Able to be dissolved or liquefied
- **Enteric**: Having to do with the digestive tract or intestines. An enteric-coated medicine will treat a patient by passing through the stomach and dissolving in the intestines
- **Simulation**: Using a model to test the outcome of a certain situation
- **Control**: The variable/element of an experiment/simulation that is unchanged during the test

Materials

Scientist Volunteers will bring:

- Digestive System image, laminated (1)
- Engineer Design Process Signs, laminated (5)

- Worksheets (1 per group)
- Paper plates (1 per group)
- Spoons (1 per group)

- Flour (60 mL per group)
- Cornstarch (30 mL per group)
- Sugar (60 mL per group)
- Vegetable oil (30 mL per group)

- Clear plastic cups (1 per group)
- Clear diet soda (2 L bottle per class visit)
- Color-coated candy (Skittles)

- Cleaning materials (paper towels, wipes, trash bags)

Materials teachers should provide:

- Pencils
- Newspaper, if possible

Classroom Set-Up

Students should be set-up to work in groups of 2 or 3 individuals. We will need a sink to dump out the soda after the experiment. The activity has the potential to be very messy, so we will need the class to understand the importance of keeping their experiments clean. If the teacher has newspaper available, we can lay that around desks in case of spills.

Classroom Visit

1. Introduction (10 minutes)

Role Model Introduction:
Being a role model is an important part of being a BASIS volunteer! Begin your lesson by introducing yourselves! Every team member should take a moment to explain who they are and what they do as an Aduro employee/scientist/engineer/science-enthusiast. Feel free to tell your "story," as if giving an elevator pitch to kids: Why did you become a scientist? What questions are you trying to figure out? What do you do in your job? Why should students relate to you? Feel free to bring in photos, specimens, and other props. Let your personality shine through!

For this particular lesson, role model introductions should wait until later in the lesson while experiments are running to allow the pill coating to dissolve.

Topic Introduction:

Your topic introduction should follow the outline below. As much as possible, try to frame this information as questions posed to the class, rather than as a lecture. This helps activate students' prior knowledge and facilitate student-guided conversation.

- How many of you have ever had a fever, headache or stomach ache? What can we do to make ourselves feel better when we are sick? [Rest, drink liquids, take medicine]
- Has anyone taken medicine before? Was it a liquid or a solid? [Many kids will use liquid medication and not swallowed a pill before] Have you ever seen a bottle of pills before, like Tylenol or allergy medicine? When you get older, you will probably take medication in pill form!
    - Note: While it's important to help students relate to the lesson, it's also important here to protect their privacy. Avoid asking kids about medical experiences they or their family members have had. Keep it general.
- Taking medication when we are sick can be very important, but medicine can be hard on our stomachs if they **dissolve** there [Define, write on board].
- What do you know about the stomach? Where is it in the body? What is its role in digestion? [Show students image of digestive system using the classroom document camera] Why might it be sensitive to medicine?
    - Note: At minimum, students need to understand that food (and medicine) passes through the stomach, then into the intestines; and that the stomach breaks food down with churning actions and stomach acid. If they have not already learned this, help them understand it!

- Because our stomachs can be sensitive to medicines, a lot of work goes into designing those pills and the coating on those pills! Varying the material and thickness of the pill coating can have a huge impact on the medication's effect on the body.
- What could we do about the problem that a pill could dissolve in our stomach and give us a stomach ache – making us feel worse instead of better! How could we solve this problem? Could we do anything to the pill to make it better for our bodies? [Think-Pair-Share student ideas]
- It sounds like this is a problem for an engineer! You are all going to be engineers today and solve this problem! Specifically, you will all be **bioengineers**.

- Introduce **bioengineering** [Write **bioengineering** on board]
  - Guide students to see if they can figure out the definition: what does bio signify? What is engineering?
  - Engineering is a way of finding solutions to problems using science and math. Problems may be big or small.
  - Bioengineers find solutions to problems that have to do biology, or life!

Teaching Tip: Guide Group Discussion

- Write new vocabulary words and brainstorm lists on the board
- Refer back to the board to engage visual learners and English Language Learners
- Give students 3 seconds to think before calling on anyone
- Be aware of examples you use that may not be accessible to all students: for example, some students may not have ridden a roller coaster, been on an airplane, played with a smartphone, or even been outside of their hometown!
- Guide students to figure things out together by turning statements into questions
  - Instead of saying: "A baseball cap has been engineered to solve the problem of how to keep the sun out of our eyes."
  - Try: "Can you think of an example of something in this classroom that has been engineered? What about that baseball cap hanging up by the door? What problem does it solve? How does it solve that problem?" etc.

- Bioengineers have come up with protective coatings for pills so that pills don't dissolve in our stomachs and give us stomach pain. Instead, these medicines pass right through our stomach and into our intestines, just like food does. (Again refer to visuals/props). These are called **enteric**-coated medicines [Define, write on board].
  - Can you think of any other benefits to adding a coating to medication? (eg protecting the pill during packaging/handling; protecting the pill from temperature/moisture/light when it's stored; manage the rate at which the dose is taken up; provide a surface to print the name of the medication on the pill; making the pill more attractive; etc.)
- Today, as bioengineers, we're going to try to figure out how to put a coating on a pill so that it doesn't dissolve in the stomach, but *is* **soluble** [Define, write on board] in the right place. We'll act as engineers to develop our own **enteric** coating. In groups of [2-3], we'll create a recipe for

our coating, then test it by observing its effectiveness in protecting a piece of candy in an environment that **simulates** [Define, write on board] the environment found inside our stomachs. Then, just like all engineers, we'll analyze our coating and try to improve it.

- Why do you think it might be useful to test a pill in a simulated environment, instead of in an actual stomach? (eg we can observe it more easily)

Teaching Tip: Differentiate for grades 3, 4, and 5

- Ask the teacher about students' background with engineering and the digestive system ahead of time, so you can adjust vocabulary and the complexity of concepts.
- For example, some classes may have learned the digestive system; others may never have heard of it! You'll want to adjust your class discussions accordingly.
- Come prepared with plenty of visuals (images, props) to help convey concepts in an engaging, accessible way.
- Adjust the criteria and constraints of the challenge based on the grade level and class background with engineering.

2. Learning Experience (45 minutes)

- Begin by introducing students to the **engineering process:**
- Add the first step of the engineering design process on the board "**ASK**". The first step that an engineer does is ask what the problem is and know what materials you will have:

Step 1: ASK: Define the problem

- Reiterate the problem that students are trying to solve: How can we create a pill that is **soluble** but will not dissolve in the stomach, to avoid stomach aches?
- Introduce the **criteria** (write on board, define)
  - What kinds of characteristics do you think our pills should have to be successful? What concerns do we have?
  - For today's purposes, the pill must dissolve in soda as slowly as possible.
- Introduce the **constraints** (write on board, define)
  - Students can use only the materials provided (oil, flour, sugar, cornstarch)
  - Students will use the worksheet to create a recipe for the amounts of each ingredient they will use. They can ONLY use 6 spoonfuls total. (e.g. 3 flour, 1 oil, 1 sugar, 1 cornstarch OR 1 flour, 3 oil, 1 sugar, 1 cornstarch)
  - The coated pill must be thin enough to swallow. The pill should have a thin and sleek design so that it's easy to swallow, inexpensive to ship, and requires less packaging.
- Challenge students to ask questions that will clarify the criteria and constraints
  - Check to be sure everyone understands

Step 2: **IMAGINE AND PLAN** Solutions

- Add "**IMAGINE**" and "**PLAN**" to the engineering design process on the board. In a moment you will imagine and plan your design with your partners. Make sure that you listen to your partnesr, share your own ideas, and work together to come up with a single plan for your pill coating!
- Pass out worksheets to each group.
- Guide the class in a discussion about the properties of each ingredient. What do students observe? What background knowledge can they bring to the challenge? Record responses on the board. Also guide students to the following information which they may or may not know on their own:
    - 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. *Tip: if groups have trouble with very sticky solutions, encourage them to try more flour or cornstarch*.
    - 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.
- Before any mixing is done, have student teams decide amongst themselves how much of each ingredient (in teaspoonfuls) they want in their coatings. These become their recipes, which they document on their worksheets. Limit to 6 teaspoons total
- Add "**CREATE**" to the engineering design process on the board.
- Have student groups bring their recipes up to the station that has all ingredients. Help students add their ingredients from their recipe onto their plate.
- Once they have all ingredients from their recipe, students go back to their seat. Direct students to begin mixing their coatings on paper plates. 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.
- When all groups have finished creating their coating mixture and recipe, hand out one piece of candy to each team and have them apply the coating to it. [While this is happening, fill a plastic cup half full with clear soda for each team, 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). This is the **control**. Label the cups with a marker so each group's cup can be easily identified.
- When all of the groups are finished, call their attention to the front with the cups. Discuss what a **control** [Define, write on board] is and why it is used. Ask the class: why is it important to have a control?
- Have a representative from each bring their coated candy to the front of the class.
- With the timer ready, and at the same time, have students drop their coated candies into their cups of clear soda, while the scientist volunteer drops an uncoated candy into its cup of clear soda as a **control**.
- Allow the candy to sit in the soda for 10 minutes.
- Guide a group discussion:

  - How does this step simulates a pill going through the human digestive tract? (Answer: This simulates the acidic environment of the stomach.)
- While waiting, provide role model elevator pitches and lead discussion with students.
- After 10 minutes have passed, have students remove their pieces of coated candy from the soda-filled. 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?
- For older students, have students calculate on their worksheets the fractions represented by each ingredient in their recipes. Compare recipes among teams, and discuss as a class, using the board. What are the relationships between performance and proportion of certain ingredients? What are the advantages and disadvantages of using certain materials? What effect did thickness of the coating seem to have?

Step 3: **IMPROVE**: Optimize

- Emphasize that engineers "**IMPROVE**" (add to design process) and often have to test and re-design many times before they find a solution that works!
- Using what they learned from analyzing the testing results and original recipes, have each group write down a new and improved coating recipe. 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.
- Repeat the same procedure for coating and testing.
- While you wait, you can guide a discussion: For example, discuss the possible drawbacks or advantages to using a higher proportion of certain ingredients, aside from the coating's performance during the test phase. (Eg a high proportion of sugar makes the pill taste better and easier to swallow, a high proportion of flour or cornstarch makes the coating more workable and allows for a thinner application, which decreases packaging and shipping costs, etc.). Ask students to describe the balance that we are trying to achieve with all these variables. (Eg: We're trying "protect the pill," but also get the most other advantages and the fewest other disadvantages.)

3. Wrap Up: Review and Discuss the Learning Experience (3-5 minutes)

Compare the results again as a class. What improvements were made? How did it help us as engineers to test and then optimize?

4. Connections & Close (3-5 minutes)

Connections to the real world around students:
What other biomedical engineering projects can students imagine they might want to work on in the future? What problems would they solve?

Close: Wrap up as a role model by leaving a few minutes for students to ask questions about science or engineering, about being a scientist/engineer, and about becoming a scientist/engineer. Then, thanks and goodbye!

Follow Up: After the Presentation

Teachers who wish to extend the impact of this lesson may find the following CRS web pages useful:

- http://www.crscience.org/educators/helpfulreports
- http://www.crscience.org/educators/treasuretrove

Standards Connections

NGSS:

- Connections by topic
  - 3-5 Engineering Design
  - 4 Life Science: Structure and Function
- Connections by disciplinary core ideas:
  - 3-5-ETS1 Engineering Design
  - 4-LS1 From Molecules to Organisms: Structures and Processes
- Connections by scientific & engineering practices
  - 2. Developing and using models
  - 3. Planning and carrying out investigations
  - 4. Analyzing and interpreting data
  - 6. Constructing explanations and designing solutions
- Connections by crosscutting concepts
  - 3. Scale, proportion, and quantity
  - 4. Systems and system models
  - 6. Structure and function
  - 7. Stability and change
- Connections by performance expectation:
  - 3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
  - 3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
  - 4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

FOSS: 5th Grade Module: Living Systems. Investigation 3: Transport Systems.

CRS
WWW.CRSCIENCE.ORG
COMMUNITY RESOURCES FOR SCIENCE

NC STATE Engineering

The Engineering Design Process

ASK
- What is your design supposed to do?
- How will you know if it is doing what you want? What could keep you from making it do that?
- How will you test your design?

IMAGINE
- Apply knowledge and creativity to brainstorm ideas together.
- Agree on one to try!

PLAN
- Consider your materials and resources.
- Sketch/draw the details.
- Pitch your plan.

CREATE
- Follow the plan.
- Test it out and compare your results to what you wanted or expected.

IMPROVE
- Analyze your test results.
- What change would make the biggest impact on meeting your goal?

Goal: New or improved product, process or system.

- The engineering design process is a series of steps that you repeat to develop or improve a product, process or system. You can start anywhere in the process, however, most engineers begin at **ASK** or **IMPROVE**.
- Failure is always a part of the process ... so is learning from failure!

Design process adapted from the Museum of Science Boston "Engineering is Elementary" program.

the engineering place

Name: ________________________________ Date: ________________

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		

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