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BASIS Lesson Plan

Lesson Name: Materials and Structures

Grade Level Connection(s)

NGSS Standards: K-2 Engineering
FOSS CA Edition: Grades 1-2 Balance and Motion

**Note to volunteers: The BASIS Program Manager will discuss how to adapt this lesson for grades K, 1, and 2 in your coaching session (for example, vocabulary or criteria will change). This lesson plan is a general guideline, base roughly on 1st grade.*

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

Teaser/Overview

This hands-on lesson introduces students to engineering through a fun, team-based challenge. Students will explore the relationship between materials and structures by working collaboratively to design and build a paper structure capable of supporting a medium-sized book.

Lesson Objectives

- Students will work together to conduct a collaborative engineering challenge.
- Students will understand that the strength of a structure is not just determined by the strength of its materials, but also by the way its materials are shaped.
- Students will learn that engineers can conserve resources by arranging materials in carefully designed and creative ways.
- Students will understand the values of teamwork, design, optimization/improvement, and "failure" in the engineering process.

Vocabulary Words

- **Engineering:** Finding solutions to problems using math and science.
- **Criteria:** How we measure success; how we know our solution is successful.
- **Constraints:** Limitations or restrictions (eg time, money, materials, space, human resources)
- **Structure**: How something is made or put together (eg its shape)

- **Function**: What something does; its role
- **Properties:** Characteristics; things that describe something
- **Corrugation**: Shaped into ridges and grooves

Materials

Volunteers will bring:

- Paper
- Paperback books
- Tape
- Styrofoam cups
- Cardboard box
- Egg carton
- Rulers

Teachers should provide:

- Lab notebooks (or paper for students to write on), pencils

Classroom Set-Up

Students should begin on the carpet if possible; if not, students should begin facing the front. Students will then break into groups of 3-4.

Classroom Visit

1. Introduction (15 minutes)

Role Model Introduction:
Being a role model is an important part of being a BASIS volunteer! Begin your lesson by explaining who you are and what you do as an engineer. Feel free to tell your "story" as if giving an elevator pitch to kids: Why did you become an engineer? What problems are you trying to find solutions to? What do you do in your job? Why should students relate to you? Feel free to bring in photos, specimens, and other props. You may also wish to weave your own projects in as examples throughout the lesson!

Topic Introduction:

1. Introduce **engineering** (write on board)

- Activate students' prior knowledge with a group discussion: What do you know about engineering? What do engineers do? What kinds of projects to they work on? What kinds of things do they build? (This also helps you to adjust the lesson according to the class's background).
- Engineering is a way of finding solutions to problems using science and math.
- Problems may be big (how to we get cars across the SF Bay?) or small (how can we keep our heads dry when it rains?)
- What do you see in our classroom that has been engineered? What problems have been solved by creating, improving, or building something? (eg shoes help us walk without hurting our feet; a computer helps us record and learn things, communicate, and play games; the walls help us display things and keep sounds from going from one room to another; etc.)

2. Introduce structures and materials (the following examples are tried and tested, but feel free to come up with some of your own!)
    - How many of you have ever engineered something? Maybe you've built something! What are some things you've built?
    - Engineers have a special word for things that they build: **structure** (write on board).
    - When you build a structure, what do you use to build? Blocks? Legos? What else? The things that we use to build structures are called **materials** (write on board).
    - When you build, are your structures easy to knock over or hard? Why? Can you remember how it looked? How did you make it? What was it made out of? What did you do to make it strong?
    - Different materials have different **properties** (write on board) that make them better or worse for building certain structures.
        - Styrofoam example: [show cup] what are some properties of Styrofoam? What if you tried to build a chair made out of this piece of styrofoam? Do you think that would work? (Show of hands: yes vs. no) Why do you think yes? Why do you think no?
            - Sometimes, materials can surprise you! Several Styrofoam cups together can hold up a heavy book [invite a student to demonstrate]
        - Egg carton: [Hold up/pass around a piece of cardboard cut from an egg carton] Does anyone know what **structure** this is from? What material is it made from?
            - How strong do you think this thin, flimsy paper is? What could we do with it? Well, you can stack these up very high and they will still protect the eggs inside from getting crushed!
    - Engineers have many ways to make a strong structure out of a weak material!
        - Cardboard box: How many of you have ever put things into a cardboard box? What kind of things can you put in there? How much weight can a cardboard box hold?
        - Has anyone ever taken apart a piece of cardboard to see what is inside? [Demonstrate by peeling apart a sheet of cardboard in from of them.]
        - This wavy part is called **corrugation**: it's what allows us to make a strong piece of cardboard using only three thing pieces of paper.

    - Imagine if we tried to make a strong piece of cardboard by just stacking sheets of paper together – it would take a LOT more paper! That box would weigh so much that it would be hard to lift it, even without anything inside.
- Engineers have lots of good reasons for finding ways to make strong structures out of weak materials.
    - Who has seen a car tire? [show images or bring in a small tire to engage visual learners] What is it made of? What's inside?
    - Why do cars and trucks use tires, instead of just a solid wheel of rubber? (Materials cost, better function, friction, shock-absorbing…)
    - Why does a big truck have more than four tires?

Teaching Tip: Guide Discussion in grades K-2

- Refer to vocab on the board to engage visual learners and English Language Learners.
- Be mindful of grade level by simplifying concepts or using more accessible examples.
- Be aware of examples 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!
- Wait 2-3 seconds before calling on anyone to answer a question.
- Consider using "pair-share" technique to encourage participation: instead of taking answers right away, have students turn to a partner to share first.

2. Learning Experience (30-40 minutes)

- We've seen how structure can play a big part in the strength of an object. Now it's time to put it into practice!
    - Split students into groups of 3-4 before explaining the engineering challenge.
    - Each group will be given paper, tape, and a book.
    - Using ONLY these materials, groups need to work together to build a structure that can support the book 6 inches (two fists) above the table (introduce the vocabulary word **criteria** if appropriate).
    - Groups can use as much paper and tape as they want, but the structure can't be taped to the table; and they'll have 10 minutes to work (introduce the vocabulary word **constraints** if appropriate).
- Conduct the challenge
    - Observe groups' progress and ask them to tell you what they are trying, observing, concluding. Why did they decide on the structure they did?
    - Let students know when there is one minute left.
- Guide a group share
    - Have each group share with the class what they have built, and why.
- Conduct the tests
    - Emphasize that engineers often have to test and re-design many times before they find a solution that works! Give examples: are we still driving cars like the ones our

grandparents drove? No, every year engineers improve upon car designs. Will we be driving the same cars in the future? No, engineers will continue building on each other's solutions.

- Stage 2: Give groups 10 minutes to optimize their design or address a greater challenge.
    - For older/more advanced classes, tighten the constraints: In the real world, engineers have to work with a limited amount of time and money, so they might not be able to do exactly what they want. This means that we have to learn to work with smaller amounts of materials. Sometimes we also have other restrictions like size, shape, or even appearance! Often, we have to make compromises that we call "trade-offs." [Give examples of trade-offs, like cutting out an extra feature to save space/money, spending more money on a higher-quality material, etc.]
    - As engineers, your job is now to build a structure that can support the same book 6 inches above the table using only [X] pieces of paper. You'll have 10 minutes to work on your structure, and then we'll have you share your structure with the class.
    - (For younger students, have groups "optimize" their structure by working to improve it).
    - Observe groups' progress and ask guiding questions.
    - Let students know when there is one minute left.
- Test again.
    - If some groups are still not successful, feel free to give them a moment to make additional adjustments.
- Have the groups share their structures again, and discuss what they observed while they were building.
    - Discuss that paper is a weak material, but when shaped in certain ways, it can become very strong!

Teaching Tip: Differentiate for grades K, 1, and 2

- Ask the teacher about students' background in engineering, and adjust constraints and criteria accordingly.
    - A kindergarten class with no experience may need more relaxed constraints or criteria. The least experienced classes may need to have constraints or criteria removed, and engage in a more "exploratory" challenge.
    - A 2nd grade class with lots of experience may need a follow-up challenge with more advanced criteria.
- Ask the teacher about their students' experience with teamwork. In some K classes teamwork may still be a challenge, so the teacher may recommend using pairs.

3. Wrap Up: Review and Discuss the Learning Experience (10 minutes)

- Return the class to the carpet for a wrap-up discussion.
- What are some things that you learned today about materials and structures? Did you see anything that surprised you? What was difficult? What 'hints' helped the most? What did you learn?
- What if you wanted to use popsicle sticks to support a book? How would this be different? How are the properties of popsicle sticks different from the properties of paper? [Stronger material—maybe they will say that this is better. If so, point out that this is true, but they are more expensive, more complicated, would take longer, would need glue, etc.] What do engineers call these differences? [trade-offs]

4. Connections & Close (5 minutes)

Connections to the real world around students:

From now on, pay attention to the structure of the things around you. How did engineers use good design? What are some of the trade-offs they might have made? Take a photo or draw a picture of something you observe that has an interesting structure or interesting material properties.

Close:

Wrap up as a role model by leaving a few minutes for students to ask questions about science, about being a scientist, and about becoming a scientist. 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
  - Engineering: K-2. Engineering Design
  - Physical Science: Grade 2: Structure and Properties of Matter
- Connections by disciplinary core ideas:

K-2-ETS1 Engineering Design
2-PS1 Matter and Its Interactions

- Connections by scientific & engineering practices
  1. Asking questions and defining problems
  3. Planning and carrying out investigations
  6. Constructing explanations and designing solutions
- Connections by crosscutting concepts
  2. Cause and effect: mechanism and explanation
  6. Structure and function
- Connections by performance expectation:
  K-2-ETS1-2. Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.
  K-2-ETS1-3. Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.
  2-PS1-1. Plan and conduct an investigation to describe and classify different kinds of materials by their observable qualities.
  2-PS1-2. Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.

FOSS Connections: Grade 1/2 Module: Balance and Motion; Investigation 1: Balance