Lesson Plan: Bridge Builders - Mastering Shapes and Strength

Subject: Engineering, Physics, Design Thinking
Ages: 9-13 (Optimized for 11-year-olds)
Time Allotment: 60 minutes

Materials Needed

- For each participant/team:
  - 30 plastic straws or popsicle sticks
  - 1 yard (about 1 meter) of masking tape
  - A pair of scissors
- Two stacks of books of equal height (to create a gap or "canyon")
- A small cup or container to hold weights
- A collection of uniform weights (e.g., pennies, washers, Lego bricks)
- Paper and pencil for planning
- A ruler
- Optional: A rubber band and a small sponge for demonstration

Learning Objectives

Building on our last lesson where we learned the Engineering Design Process, by the end of this lesson, learners will be able to:

- Apply all five steps of the Engineering Design Process (Ask, Imagine, Plan, Create, Improve) to a new challenge.
- Define and identify the forces of tension (pulling) and compression (squeezing) in a structure.
- Explain and demonstrate why a triangle is a stronger shape for construction than a square.
- Construct a bridge that spans a set gap and supports a measurable weight.

Lesson Structure

Part 1: Review & Introduction (10 minutes)

Review of Previous Lesson

Educator asks: "Last time, you were all brilliant engineers in the Marshmallow Challenge. Who can remind me of the five secret steps in the Engineering Design Process we used?" (Guide them to recall: Ask, Imagine, Plan, Create, Improve). "What did we notice about the towers that were the strongest and tallest? What shapes did you see in their bases?"

The Hook

Educator says: "You mastered building tall structures. But what if you need to build across something, like a river or a deep canyon? That's what we're doing today. We're moving from skyscrapers to bridges. Your new challenge is to design a bridge that can hold as much weight as possible. But to succeed, we need to unlock a secret that engineers have used for thousands of years: the power of shapes and hidden forces."

State the Challenge & Objectives

Educator sets up the two stacks of books about 10 inches apart. "Your 'Ask' or problem is this: you must build a bridge that spans this 10-inch gap using only 30 straws and tape. Your goal is to make it strong enough to hold a cup of weights. Today, we're not just going to build; we're going to learn *why* some bridges stand and others fall by exploring forces and the world's strongest shape."

Part 2: Body of the Lesson (35 minutes)

I Do: Introduce Forces and Shapes (10 minutes)

Educator explains: "Every structure, from our marshmallow towers to the Golden Gate Bridge, is affected by invisible forces. The two most important are tension and compression."

- **Demonstrate Compression:** "Compression is a squeezing or pushing force." (Educator squeezes a sponge). "When you add weight to the top of a bridge, some parts get squeezed. That's compression."
- **Demonstrate Tension:** "Tension is a stretching or pulling force." (Educator stretches a rubber band). "Other parts of the bridge get pulled apart. That's tension."
- **Connect to Shapes:** "Now let's see how shapes handle these forces." The educator quickly makes a square and a triangle out of straws, holding them together loosely with tape at the corners.
    - "Watch what happens when I push on the side of this square." (It easily collapses and changes shape). "Squares are not good at handling forces from the side."
    - "Now, watch the triangle." (Push on the side of the triangle; it holds its shape). "A triangle is incredibly strong! When you push on it, it turns that pushing force into both tension and compression along its sides. This is called a 'truss,' and it's the secret to almost every strong bridge."

We Do: Plan the Bridge (5 minutes)

Educator facilitates a Think-Pair-Share or group discussion:

- "Now that we know triangles are the key, how can we use them to build our bridge?"
- "Let's imagine some designs. Should we make a flat roadbed with triangle supports underneath? Or maybe triangles along the sides, like a truss bridge?"
- "Take 3 minutes and 'Plan' your design. Draw a side view of your bridge. Make sure to draw in the triangles you will use to give it strength. Label one part you think will be in compression and one part you think will be in tension."

You Do: Create! (20 minutes)

Educator says: "Alright, engineers, you have your plans and your materials. Remember the rules: 10-inch span, 30 straws max. You have 20 minutes to 'Create' the strongest bridge possible. Go!"

- Start a timer.
- Circulate and use probing questions for formative assessment, connecting to the day's concepts:
    - "I see you're using a lot of triangles. How do you think that will help your bridge handle the weight?"
    - "When you place the cup in the middle, which straws do you predict will be squeezed (compression) and which will be pulled (tension)?"
    - "You're halfway through! Is your plan working? What's one thing you might need to

'Improve' as you build?"

Part 3: Conclusion (15 minutes)

Test and Analyze

Educator gathers everyone for the testing phase. "It's time to see what our engineering skills have produced! Let's test these bridges for strength."

- One at a time, each learner/team places their bridge across the "canyon."
- They place the empty cup in the center of their bridge.
- Slowly, they add weights (pennies, washers) one by one, counting aloud.
- The test ends when the bridge visibly bends, breaks, or collapses. Record the number of weights held.
- Celebrate every result. A dramatic collapse is an excellent learning moment!

Recap and Reflect

Educator leads a final discussion to summarize the learning journey:

- "What did the bridges that held the most weight have in common?" (They almost certainly used many well-constructed triangles).
- "Where did your bridge fail? Was it a failure of tension or compression? How do you know?"
- "Let's connect this back to our first lesson. We used the same five steps of the Engineering Design Process, but this time we added new knowledge about forces and shapes. How did that help you build a better structure?"
- "If you were to do this again, what is the number one 'Improvement' you would make to your design, based on what you saw today?"

Educator reinforces the takeaway: "Today you leveled up as engineers. You not only followed a process, but you also used scientific principles to solve a problem. You controlled forces, used shapes for strength, and built something that could do real work. That is the core of what engineering is all about."

Assessment & Success Criteria

- **Formative (During the lesson):** Learner's sketch includes triangles. Learner can answer questions about why they are incorporating triangles into their design.
- **Summative (End of lesson):** The learner's understanding is demonstrated by:
  - Constructing a bridge that successfully spans the gap and holds at least some weight.
  - Verbally explaining that triangles were used to make the bridge strong.
  - Correctly identifying either tension or compression in their bridge design (e.g., "The top part was getting squeezed when we added weight.").

Differentiation and Extension

- **For Younger or Struggling Learners:**
  - **Scaffolding:** Provide a simple diagram of a truss bridge for them to copy. Focus on the physical construction and the concept that "triangles are strong."
  - **Success Criteria:** Success is building a bridge that spans the gap and using triangles in the design.
- **For Advanced Learners (like Vienna):**
  - **Extension:** Challenge them with additional constraints, such as building a bridge with the

highest strength-to-weight ratio (they must weigh their bridge first, then divide the weight held by the bridge's own weight). Or, challenge them to build an arched bridge.
    - **Success Criteria:** Success includes a robust design and the ability to clearly articulate how both tension and compression are at work in different parts of their bridge.
- **Follow-Up Activity:** Introduce a budget. Give each material a cost (e.g., straws = $100, 1 inch of tape = $20) and a budget of $4000. Challenge them to build the most efficient bridge for the lowest cost.